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Progress in Locomotive Design*

Improvement and Refinement Tending to Greater Economy in Operation

THE past year has brought important but not spectacular developments in locomotive progress. There has been much concentration on more effective use of fuel through fuel saving devices and capacity increasing factors and a marked tendency toward maximum power per unit of weight has developed. The important and helpful tendency toward co-operation on the part of engineers of the supply interests should be recognized and is being encouraged.

In a general way, the progress can be indicated and the present situation demonstrated by the following:

(1) Locomotives of the largest size for the different classes of service continue to be built almost exclusively. A beginning has been made toward applying the most economical arrangements and proportions to the lighter locomotives.

(2) Boiler capacity per pound of metal in the boiler has been decidedly increased by the use of larger fireboxes and combustion chambers, thus giving time for the completion of the gas reactions before the flues are reached. Shorter flues, giving a higher rate of evaporation per unit of area, are the result in some cases. Flues, however, in no case, are shortened from the front end, and, having the size of firebox and combustion chamber desired, the flues are made as long as the weight limits will permit.

(3) Cylinders are increasing in relative size due to the lower steam consumption at shorter cut-offs when using superheated steam. Stokers are also causing enlarged cylinders because of the increase in the maximum boiler capacity.

(4) Heavier weights are being placed on drivers in connection with the lighter weights of reciprocating parts.

(5) Superheaters and brick arches are almost universally applied to new locomotives and are also being installed on many older designs.

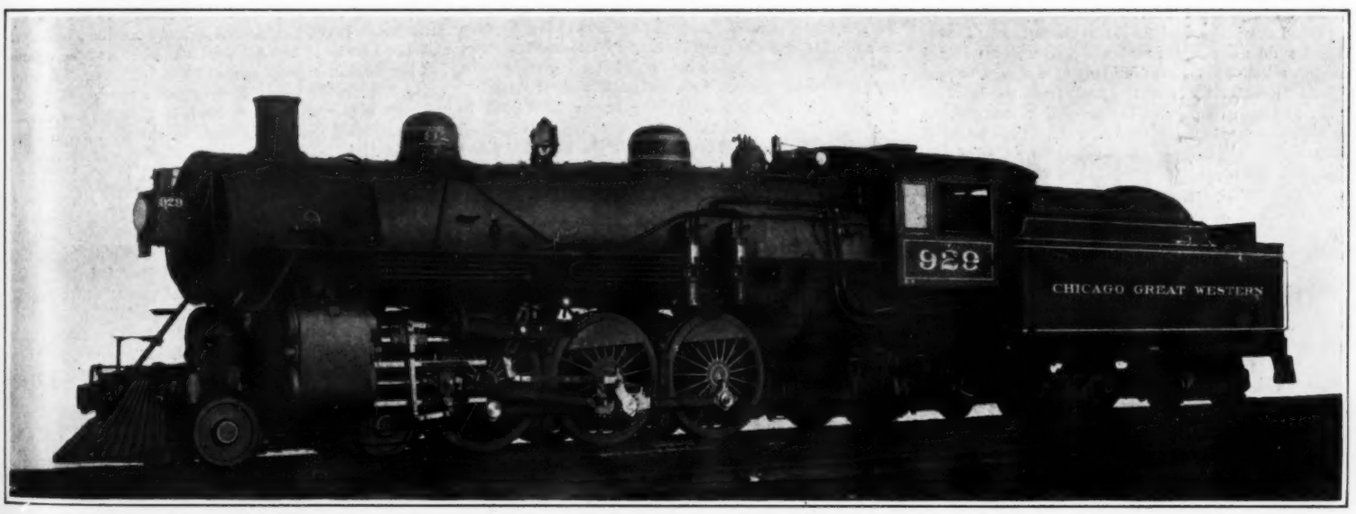
(6) Standardization of the parts most frequently requiring repairs and the use of these parts on new locomotives as far as possible, is being more widely practised.

In these days of diminishing and disappearing net earnings, higher average train loads must be handled. Locomotives are now being called on for results which but a few years ago would have seemed absolutely impossible. The locomotive designers are meeting the demand and are producing Atlantic type locomotives which do as much work and haul as large trains as the Pacific type did two years ago; consolidations which perform the service that demanded Mikados in 1911, and all classes which will pull from 10 per cent to 30 per cent larger trains on the same amount of coal used two or three years ago. At the same time, if allowance is made for increases in wages and the increased cost of material, the cost of repairs per unit of work has been actually decreased.

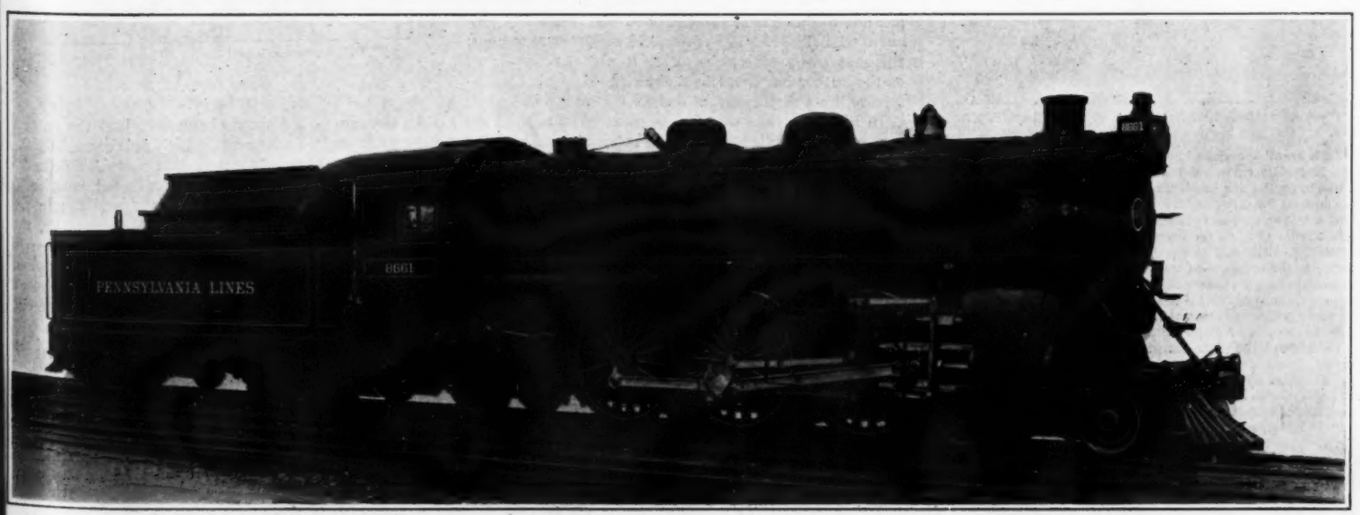
The general use of the superheater and brick arch is largely responsible for this improvement, but the adjusting of all parts to the best relationship one with the

(*Continued on page 100*)

*Reproduced from the *Railway Age Gazette*.



Pacific type of locomotive for the Chicago Great Western Railroad. Equipped with a superheater and with latest design of Gaines locomotive furnace. Cylinders 25-inch by 28-inch; 73-inch driving wheels; weight on driving wheels, 152,400 pounds; weight, total engine, 257,000 pounds.



The forty-thousandth locomotive built by the Baldwin Locomotive Works. A Pacific type for heavy passenger service on the Pennsylvania Lines west of Pittsburgh. Equipped with a superheater, brick arch and mechanical stoker, and has 26-inch by 26-inch cylinders; 80-inch driving wheels; weight on driving wheels, 189,500 pounds; weight, total engine, 293,200 pounds.

Catastrophic Instability in Aeroplanes*

The Conditions and Controlling Factors on Which it Depends

By F. W. Lanchester, M. Inst., C. E.

THE object of the present paper is to call attention to and give a brief account of a form of instability that has up till the present time been virtually ignored. In the author's "Aerial Flight," vol. i, page 277, the following note will be found:

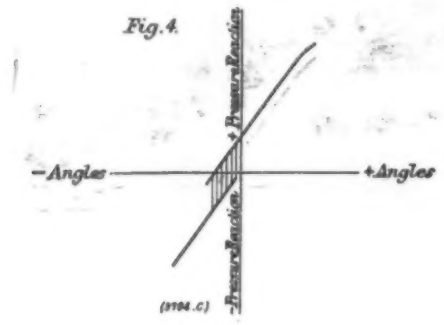
"If, secondly, we suppose that the leading edge has too much 'dip' the want of conformity is in the opposite direction, and the surface of discontinuity springs from beneath the leading edge as depicted in Fig. 2 (in contrast to Fig. 1); the result of this is destructive to the whole peripteral system of flow, for the moment the pressure region commences to occupy the upper surface of the aerofoil a condition of instability arises, and a new system of flow is inaugurated which produces a downward instead of an upward reaction. This is a fact demonstrated experimentally; a model in which the adjustment has been carried to its limits will behave in a most capricious manner, sometimes gliding perfectly and at others dropping suddenly in the midst of a flight like a bird when shot."

So far as the author is aware, the above is the only previous mention of the type of instability discussed in the present paper.

According to the suggestion contained in the quotation given, there should be a point when the attitude of an aerofoil is progressively changed, at which a sudden change in the direction of pressure takes place, a reversal, in fact, of the "lift" represented by a sudden change of sign—from positive to negative; with probably a region of ambiguity where two possible systems of flow exist.[1]

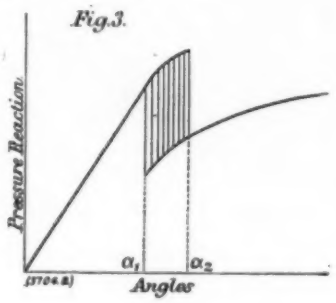
A large number of forms of aerofoil have been tested at positive and negative angles by many observers, including a comprehensive series of tests by the National Physical Laboratory, and (so far as the author is aware) no such sudden reversal or region of peripteral instability has shown itself; the curves in every case appear to pass without discontinuity from the positive to the negative region as the inclination of the aerofoil is changed. A few typical examples are given in Fig. 5. It will be noted that the point of zero reaction is not usually that of zero angle; this is a point of no importance, it arises from the purely arbitrary habit of measuring the angle of attack from the chord of the section as datum.[2]

It is evident from the above that although the fact of catastrophic instability, based as it is on actual observation, cannot be disputed, the exploration given in the author's book as above quoted requires reconsideration.



It is yet possible that forms of aerofoil will be found that will show discontinuity in the character of their pressure curve; but in absence of positive evidence, nothing of the kind can with fairness be assumed.

In the first instance we will revert to the study of the simplest of all gliding models—the ballasted aeroplane.



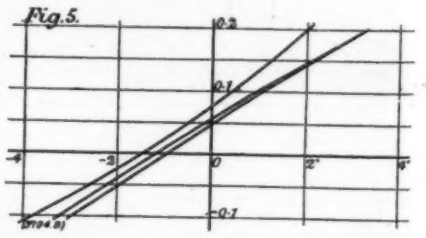
This consists merely of a rectangular plate of mica,[3] of aspect ratio = 4, ballasted by means of fishing-shot[4] at its forward edge, the center of gravity being about one-quarter of its width from the leading edge. The author has frequently demonstrated these gliders in flight before an audience, and though it is usually quite easy, at times they have a most provoking way of starting their flight on an inverted path. In connection with the present subject it is the relation of this inverted flight path to the normal flight path that we shall investigate.

At the outset there is one feature of the ballasted plane to which attention may be drawn—namely, its symmetry; briefly it has no "right side up." Now we know that if any aerodone or gliding model be launched upside down at or about its ordinary flight velocity, its flight path is entirely modified in character; referring to Fig. 6 (Fig 42 of the author's "Aerial Flight," vol. ii), a number of plottings of the theoretical flight path are given, and by a comparison of curves 2 and 11, or 3 and 10, for instance, we can appreciate the effect of the inversion of the glider at the instant of launching (at the vertical datum line these pairs of curves have the same velocity). Similarly, we might suppose an aeroplane in stable flight on a path, such as 2 in the diagram, suddenly turned over at the vertical datum line, so that its flight path becomes that numbered 11, which is past that which by convention we are accustomed to regard as the limit of stability, the machine is in the act of looping the loop. It is well that in actuality a flying-machine is not liable to be thus suddenly overthrown.

In the case of the simple ballasted aeroplane, however, we do not require to suppose the model turned over. It has no "upside down," and is in effect inverted by any cause that gives rise to a reversal of the pressure system; this may easily take place owing to a gust or eddy, or, as the author has frequently experienced to his discomforture, by a slight want of dexterity in launching.

In Fig. 7 we take *O* to be the point of launching, the two alternative flight paths, the straight glide and the tumbler curve, are shown by the two lines *O A* and *O B*. In *O C* we have the ordinary parabolic trajectory of a heavy body having the same velocity; it represents, in the equivalent case of an actual machine, the path that would be taken by the aeronaut or other heavy body not strapped in or secured to the machine. The pressure reaction in the case of the path *O A* being upward, the weight of the aeroplane is sustained. In the case of path *O B*, the pressure reaction being downward, the curvature of the natural trajectory is exaggerated in the resulting flight path. In Fig. 8 the alternative flight paths are represented more nearly as they would in practice appear; the horizontal straight line of Fig. 5 becomes inclined at approximately one seventh, as representing the coefficient of resistance or gliding angle, and the tumbler curve rapidly degenerates into an oscillatory flight path, owing to damping, which, in the case of the ballasted plane, is considerable. The diagram roughly represents the flight path in its true proportion to the figure of a man depicted for mica planes such as used for indoor demonstration.[5]

It is evident from the foregoing that the ballasted plane, stable as it is in most respects, is an implement of flight totally unsuitable for aeronautical purposes; it is, using the title of the present paper, "catastrophically unstable." Any serious eddy comprising a sudden down draught, or even the reaction following an up draught, might at any time, without the least warning, reverse the peripteral-pressure region and invert the flight path, with almost certain disaster to the machine and its occupants. But it is not the ballasted plane alone that shows this form of instability; the author has frequently seen a model, whose behavior in the ordinary way is irreproachable, suddenly, when launched in the open air, take it into its head to fly upside down. In one particular case this frequently took place when the model reached the highest point in a tumbler curve flight otherwise at the highest point when looping the loop. At this instant the flight path curvature is greatest, and the tail length tends to modify the attitude of the aerofoil in such sense that catastrophic instability will be shown. In this case subsequent flight followed an undulating path at considerably above the normal speed with the model in an inverted position.[6] There is, in fact, no reason why we should expect the phenomenon of catastrophic instability to be confined to any one form or type of flight model, though there are certain types that both theoretically and experimentally appear to be immune. Up to a certain point, the capacity of a model or machine to fly upside down may be taken as *prima facie* evidence of its being catastrophically unstable, but it is necessary to draw a distinction between models and actual machines, inasmuch as the constants of an actual machine may be altered at the will of the pilot, and so when flown upside down it may not, in the sense of the present paragraph be the same machine as when in normal flight.[7] The change contemplated as actually made by the pilot is the variation of the inclination of the tail-plane or elevator of his machine. The essential point here is whether with a single fixed setting of the tail-plane the machine is capable of being flown both the right way up and upside down. It is the setting of the tail-plane corresponding to high speed that will tend to catastrophic instability—i. e., the down-trend position. Thus it is that when an aeronaut acts to initiate a *vol plane*, or to set his machine for a very rapid descent, especially where high velocity is intended, that the greatest danger from catastrophic instability is to be feared. It seems that there should be some check or limit prescribed to the turning downward of the tail members.



In the case of the simple ballasted plane the natural velocity in its two alternative positions is essentially the same, but in the case of the aerofoil of pterygoid form the flight velocity of a model in the inverted position is commonly higher than when the right way up; in the latter, consequently, if reversal should take place, the downfall is greater. A rough estimate indicates that in the case of a flying-machine of ordinary proportions and flight speed, the extent of the drop in the event of reversal, if not corrected by the pilot, might amount to some 600 feet or 700 feet.

Having discussed in a general way the character of the type of instability under consideration, we will proceed to examine more closely the conditions and controlling factors on which it depends. We may assume that the result brought out as the general result of experiment to date, that the absence of any discontinuity in the

*Read before the British Association at Birmingham, September, 1913.

[1] Such unstable regions in the attitude of an aeroplane actually exist in certain cases. Recent experiments with a square plane in which, on the one hand, the angle is gradually increased from zero and, on the other hand, gradually decreased from 90 degrees, show that two separate curves in reality exist, and that for over certain range of angle (between a^1 and a^2 in Fig. 3) a condition of instability exists, and the pressure reaction it liable to sudden change as the conditions pass from one curve to the other. It is evident that such a condition of things implies that there are two distinct systems of flow; it is probable that in this particular case the two systems are respectively characterized by vortices transverse to the line of flight for small angles, and vortices parallel to the ends of the plane for the larger angles; the said vortices occupy the dead-water region. Between the limits of angle, a^1 and a^2, either system may persist. The idea tacitly implied in the passage cited from the author's "Aerial Flight" is that a similar condition of instability exists about the region when the reaction changes from positive to negative, as shown diagrammatically in Fig. 4. This view is negatived by the experimental evidence that up to the present has been accumulated.

[2] It is easy to see that the measurement of angles from the chord of section is an arbitrary measurement, inasmuch as an extension of the aerofoil surface, forward or backward, to follow accurately the streamline flow will give an entirely new angle as measured to the chord withiut involving an essential alteration to the aerofoil from an aerodynamic standpoint.

[3] Mica is by far the best material available for the purpose, being as stiff as tempered steel, and but one-third the weight.

[4] Lead shot split half-way through.

[5] A mica plate about 2 inches by 8 inches; weight with ballast about 6 grammes.

[6] Compare "Aerial Flight," vol. ii, section 175.

[7] In the recent experiments of M. Pegoud, for example, there is no reason to suppose that the tail-setting was the same in the inverted position as in the normal flight.

pressure reaction holds good in all cases, and that the phenomenon under discussion therefore is not due intrinsically to any properties or individuality of the aerofoil. The following may consequently be laid down:

1. There must be a change of attitude of the aerofoil simultaneously and corresponding to the inversion of its flight path.

2. The change of attitude must take place in a sense that will cause the after or tail portion to move towards the pressure side—that is to say, when the pressure side of the aerofoil changes, the tail must swing in the corresponding direction. Conditions 1 and 2 are illustrated by the behavior of the ballasted plane in Fig. 8.

3. The model being by hypothesis rigid, the change in the attitude of the tail or directive member will be of like sense and equal in degree (equal angle) to that of the aerofoil itself.

4. A flight model or machine whose mass center coincides approximately with the center of pressure of its aerofoil, fitted with a tail-plane of ample area, will be catastrophically stable (example, author's 1894 model, Fig. 9), for the directive member (the tail-plane), carrying neither positive nor negative load, cannot change its attitude as necessitated by the reversal of the pressure reaction.

5. A flight model or machine designed with the mass center forward of the center of pressure of its aerofoil, so that the tail-plane carries a negative-pressure reaction, will be catastrophically stable, for its change of attitude consequent on the reversal of the pressure reaction is the reverse to that laid down in (2). If it is capable of flight one way up, it cannot possibly be capable of flight when reversed.

6. A flight model or machine designed with the mass center aft of the center of pressure of the aerofoil, so that the tail-plane carries positive-pressure reaction, behaves in accordance with condition (2) and may be catastrophically unstable.

7. The conditions that define the limit of catastrophic stability are closely akin to those that define directional stability in the vertical plane. If both aerofoil and tail-plane follow the law that reaction varies as angle, and if the influence of center-of-pressure changes be ignored, and if the tail-plane be arranged clear of the wake stream, the limiting conditions may be regarded as identical, and it would be virtually impossible to design a model to be directionally stable and show catastrophic instability.

8. A model or machine whose tail plane or member is loaded up to a point approaching the limit of directional stability (in a vertical plane) may be catastrophically unstable as the result of one or all of the following causes:

(*a*) The aspect ratio of the tail-plane being relatively low when compared to the main aerofoil.[8]

(*b*) The movements of the centers of pressures of both the main aerofoil and the tail-plane with changes of angle (owing to these movements contributing to the directional stability without contributing to the catastrophic stability, as in the ballasted plane).

(*c*) The influence of the "wash," or downward wake stream of the main aerofoil, by its influence on the flight attitude.

From the point of view of the present paper, one is inclined to direct a certain amount of criticism to some of the features commonly met with in actual flying-machines, though it might be rash positively to assert that catastrophic instability has as yet been the cause of disaster.[9] In the author's opinion it would be wise to avoid the deliberate loading of the tail member, its function should be purely directive. The author has always found that in practice a tail carrying no load or even slight negative load is preferable in model experiments. It would also appear to be desirable to pay attention to the tail member, giving it an aspect ratio comparably equal to the main aerofoil.

With due attention to these two points, and with the reasonable curtailment of the fore-and-aft dimension of the aerofoil, giving it a good pterygoid section and aspect ratio (abandoning all idea of obtaining stability from the movement of the centers of pressure on the aerofoil and tail members in the manner of the ballasted plane), and with a "stop" or limit to the elevator or tail control, there can be very little danger in the future of any disaster from the cause under discussion. Experiments also might be made with scale models in a wind channel to determine definitely the conditions as to upside-down flight, to prescribe limits of safe-load distribution and safe tail or elevator angles of adjustment, for any given model.

Flexibility of the aerofoil has an important bearing on the catastrophic stability, classifying such flexibility as weather-vane flexibility (as in a bird's wing) and drum-skin flexibility; it may be said in brief that weather-vane stability in the aerofoil tends to stability, and drum-skin flexibility to instability.

Catastrophic stability is not definitely related to the other well-known kinds of stability involved in the problem of flight; in order to realize more completely the true position it is of interest to digress and review the different forms of instability known and comprised in the ordinary treatment (mathematical or otherwise) of the problem.

There is, firstly, the whole question of longitudinal stability, involving (*a*) the stability of the machine relatively to its transient flight path—namely, as in the stability of an arrow, and (*b*) the stability of the flight path itself in relation to the direction of gravity, as dealt with by the author in his "Phugoid Theory." Both the above (*a*) and (*b*) involve complex questions of oscillations about the position of stable equilibrium and the damping of such oscillations as may be set up by disturbing causes. Secondly, there is lateral stability (superficially analogous to the stability of a ship), in which, also, the problem is complicated by considerations of oscillatory motion; thirdly, there is directional stability, concerned mainly with rotary motion about a vertical axis; and, fourthly, there is a kind of stability known as spiral or rotative stability concerned with the interaction of motions separately considered under the last two headings. All these kinds of stability have been made the subject of previous study, both by the author's method and by the mathematical method of Dr. Bryan; but the kind of instability dealt with in the present paper is entirely external to the conditions on which the two lines of treatment mentioned are based; it is presumably owing to this fact that the possibility of what in the present paper is termed "catastrophic instability" has been so widely ignored.

In the case of a machine or model that will fly either way up there are two entirely different sets of constants, each set giving equations satisfying the conditions of stability, but there is no necessity for relationship between the two; we may, in fact, look upon the model in its two positions as two different models; in the case of the ballasted plane and other symmetrical forms the two equivalent models may be regarded as duplicate.

Although the existing theories of flight enable us to deal individually with either of the two systems of flight, of which a given model is capable, they take no account of the possibility of a translation from the one condition to the other; anything of the kind is tacitly ignored.

As a concluding illustration of the importance of the present study we may revert to the case of the ballasted plane and compare the magnitude of single gust required to destroy the longitudinal stability with that required to exceed the limit of catastrophic stability. Referring to the chart (Fig 6) we know that the limit of stability for longitudinal oscillation is reached in the case of the semi-circular path—that is to say, $\sqrt{3}$ times the natural velocity is the limit with the flight path horizontal. In other words, a head gust $\sqrt{3}-1$, or say, = 0.7 of the velocity of flight is required to bring about risk of disaster. Against this, in order to induce catastrophic instability, we only require a vertical gust well in excess of the vertical component of the angle of incidence, or, say, one sixth of the velocity of flight, so that, in the case of the ballasted plane, in order to change entirely the system of flight and induce catastrophic instability, it only requires a gust of about a quarter the magnitude that it requires to reach the limit of longitudinal stability. It is evident that where there are two systems of flight—that is to say, where a model will fly either way up—in no case can we afford to ignore the considerations raised by the present paper, and, in short any such model must be regarded with the gravest suspicion by the aeronautical designer.

[8] The importance of the relative aspect ratio of the aerofoil and tail member is due largely to the different character of the pressure law and the changing values of the constants where the aspect ratio differs in any considerable degree. It is established that for aeroplanes of high aspect ratio the reaction for small angles is approximately directly as the angle, whereas for aeroplanes of extremely low aspect ratio it more closely follows the sin² law of Newton (see "Aerial Flight," vol. I, sections 150 and 151). It is consequently possible by designing a tail like that of a pheasant, of low aspect ratio, to reach a condition of catastrophic instability without destroying the directional stability in the vertical plane. A good illustration of the effect of aspect ratio in the present connection is given by the author's experiments of a falling "T," as shown in his lectures before the Royal Society of Arts and elsewhere.

[9] The recent accident to Major Merrick, which unfortunately cost him his life, and which took place some few weeks after the reading of the paper, appears to have been clearly due to catastrophic instability.

Speeds for Turning Unusual Materials

THE *Practical Engineer* gives the following information on turning unusual materials: Slate, on account of its peculiarly stratified formation, is rather difficult to turn, but if handled carefully, can be machined in an ordinary lathe. The cutting speed should be about the same as for cast iron. A sheet of fiber or pressed paper should be interposed between the chuck or steadyrest jaws and the slate, to protect the latter. Slate rolls must not be centered and run on the tail-stock. A satisfactory method of supporting a slate roll having journals at the ends is to bore a piece of lignum vitæ to receive the turned end of the roll, and center it for the tail-stock spindle. Rubber can be turned at a peripheral speed of 200 feet per minute, although it is much easier to grind it with an abrasive wheel that is porous and soft. For cutting a rubber roll in two, the ordinary parting tool should not be used, but a tool shaped like a knife; such a tool severs the rubber without removing any material. Gutta percha can be turned as easily as wood, but the tools must be sharp and a good soap-and-water lubricant used. Copper can be turned easily at 200 feet per minute. When machining commutators that is the speed commonly used. Light cuts are taken with a pointed tool and the surface is finished with a wooden buff lined with glass paper. This buff is in the form of a 90-degree segment and is approximately 1¾ inches thick. It is held against the commutator with the point of an ordinary tool and is fed back and forth across the surface. In this way the segments are gradually ground down until there is not the slightest gap or break between the copper segments and the mica insulation. Bath stone such as is used in the construction of pillars for balconies, etc., can be turned at 150 feet per minute, and the formation of ornamental contours is quite easy. Marble is a treacherous material to turn. It should be cut with a tool such as would be used for brass, but at a speed suitable for cast iron. It must be handled very carefully to prevent flaws in the surface.—*Machinery.*

Polar Bears in Arctic Exploration.—*Petermanns Mitteilungen* and other entirely serious-minded European journals state that Capt. Sedov's Russian arctic expedition, now in the field, proposes to utilize tame polar bears for drawing the sledges of the party on its journey from Franz Josef Land to the pole.

Fig. 6 THE PHUGOID CHART THE FLIGHT PATH PLOTTED FROM THE EQUATION

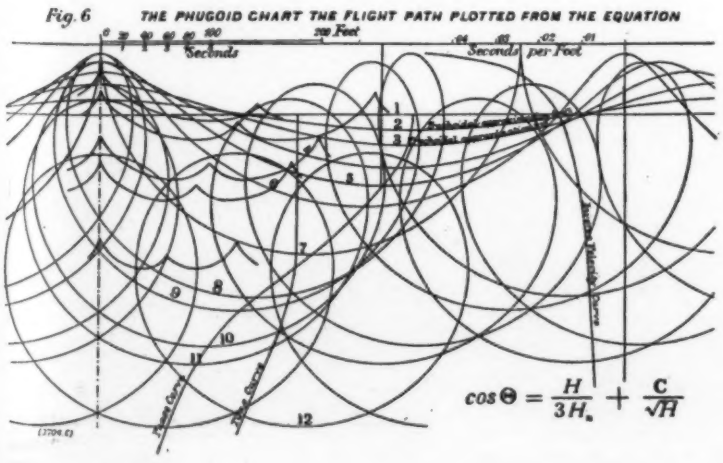


Fig. 7.

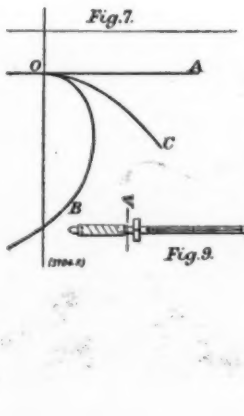


Fig. 8.

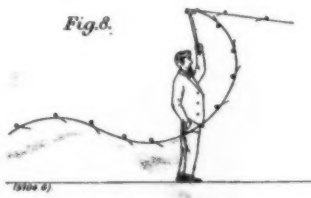
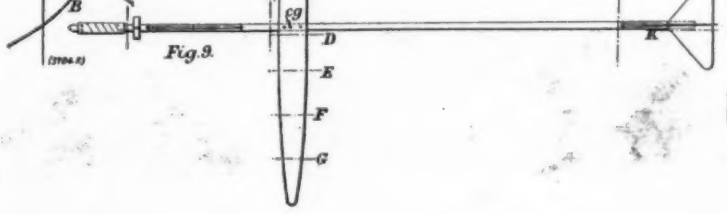
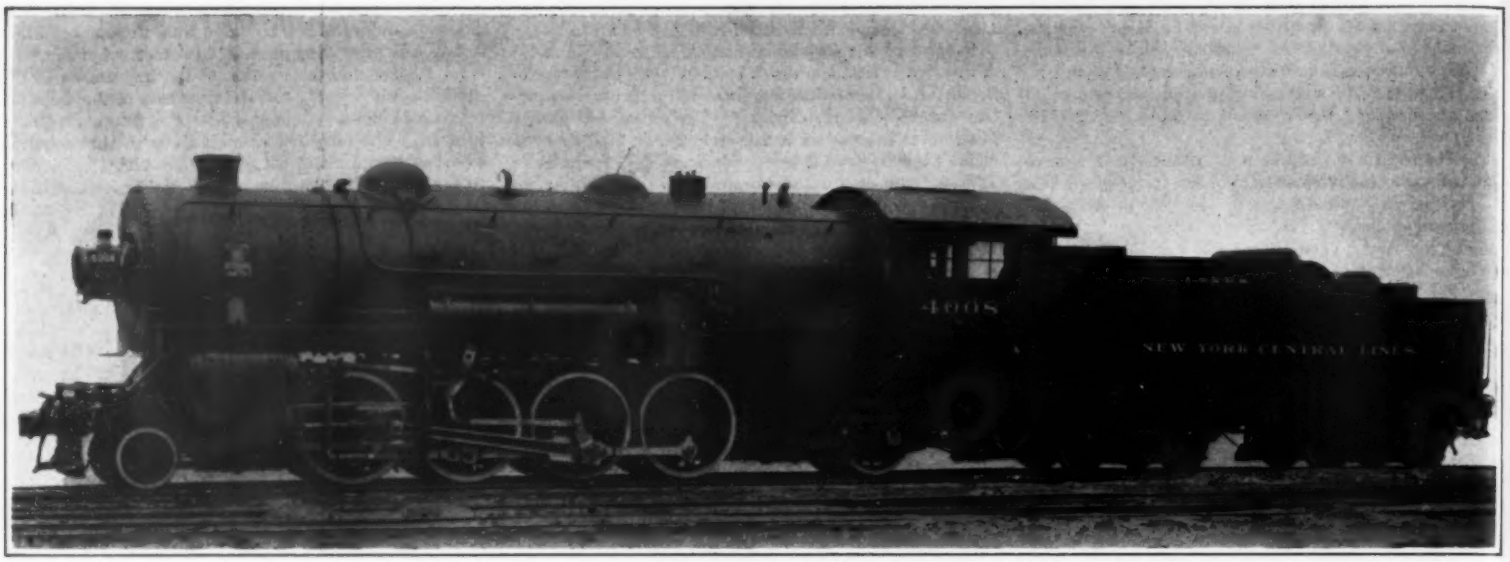


Fig. 9.





Mikado type locomotive, built for L. S. and M. S. Railway.

Progress in Locomotive Design

(*Continued from first page.*)

other has been effective in continuing the improvement.

In general the problem has been to obtain the greatest drawbar pull at the highest practical speed for the service with the least total weight of locomotive. Sustained drawbar pull depends mostly on boiler capacity, and in this direction great strides are being made. While the ratio of output in steam to the weight of the boiler is increasing, still the total weight of the boiler also continues to increase. This, in turn, means greater weight on the wheels, most of it coming on the drivers. In high or moderate speed service the permissible dead weight on drivers is controlled by the hammer blow of the excess weight in the counterbalance which is controlled by the weight of the reciprocating parts. The weight of these parts is dependent on the amount of power delivered by the cylinders, and thus the cycle is complete.

Better quality of material allows some saving of weight, and when combined with perfect design, it has permitted the use of larger boilers and heavier dead weight on drivers without exceeding the safe limits.

While there has not actually been built this year a locomotive which exceeds in total weight the 2-10-10-2 type built by the Santa Fé in 1911, which weighs 616,000 pounds, or the Virginian 2-8-8-2 type built by the American Locomotive Company in 1912, which weighs 540,000 pounds, still the average weight of new locomotives built continues to increase. Selecting ten typical examples of the 2-8-2 type built during the year, shown in the accompanying table, the average total weight is seen to be 293,020 pounds. The average for ten Pacific engines is 273,130 pounds, and for four typical consolidations the average weight is 246,875 pounds.

FEW ARTICULATED LOCOMOTIVES BUILT.

Comparatively few locomotives of the articulated type have been ordered during the past year. There appear several reasons for this: First, those companies that have physical conditions which can best be met by the use of the large Mallets have already a sufficient number in service for their requirements. Second, the increased capacity of the Mikado type made possible by the application of a stoker and superheater. Third, the revival of the Santa Fé type, also made possible by the stoker. Fourth, the general spirit of conservatism that has marked the whole locomotive situation during the year.

The Mallets ordered are all of the compound cylinder arrangement. Experience with simple Mallets has not led to any extension of this arrangement.

An articulated locomotive of very unique arrangement is being designed by the Baldwin Locomotive Works for the Erie Railroad. This locomotive will be of the 2-8-8-8-2 type, having three pairs of equal size cylinders, each being 36 inches in diameter by 32 inches stroke. The first two pairs of cylinders will be located and arranged in much the same manner as an ordinary Mallet type locomotive. The third pair of cylinders will be placed under the front end of the tender frame and will connect to four pairs of drivers under the tender. The trailer truck is also to be under the tender. The arrangement provides for compounding at the ratio of 2 to 1, and the center pair of cylinders is to use high pressure steam. One high pressure cylinder will exhaust to a receiver pipe which supplies the steam for two other cylinders. The right one, for instance, will supply the two cylinders under the tender and the left one the two cylinders at the front end of the locomotive. The exhaust from the cylinders under the tender is to heat the water in the tank and such surplus as is not required for that purpose will be discharged to the atmosphere. Exhaust from the cylinders at the front end will probably be used to furnish the draft.

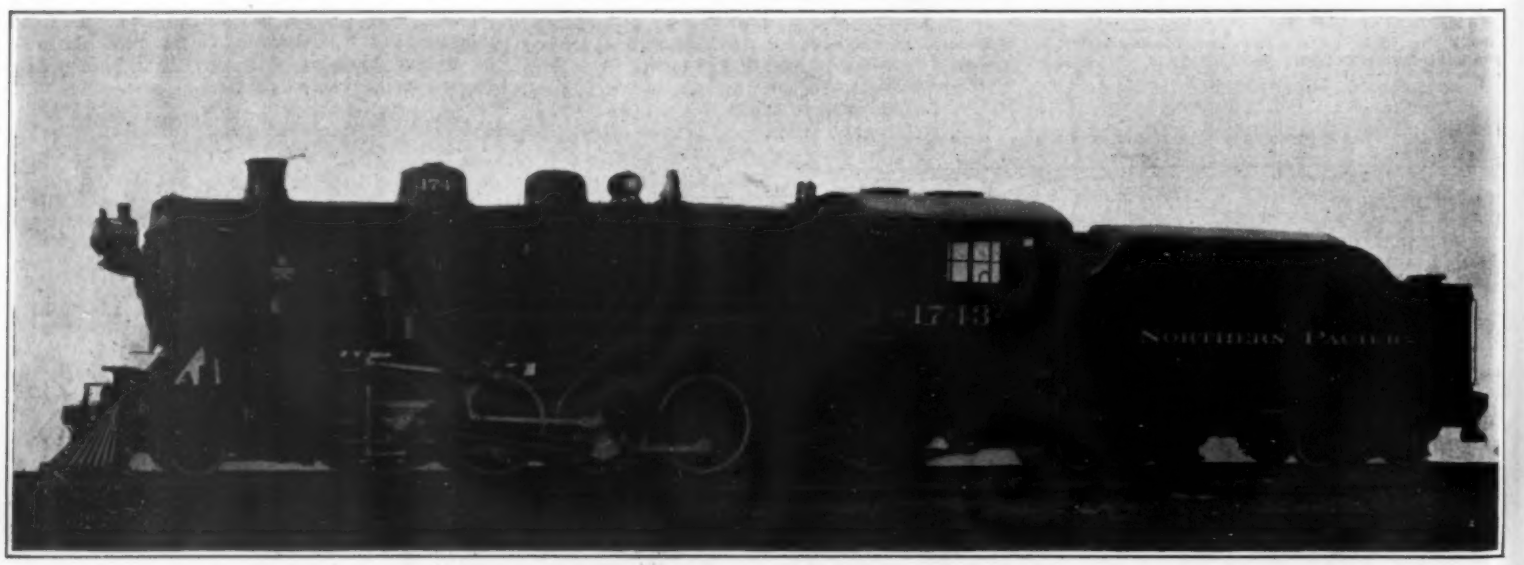
This locomotive is to have as large a boiler as can be applied within the clearance limits and the preliminary design provides for a tractive effort of about 160,000 pounds working compound. The total weight of the engine will be in the neighborhood of 800,000 pounds. These locomotives, if finally built, will, of course, far exceed in weight and size anything that has heretofore been constructed.

TYPICAL MIKADO TYPE LOCOMOTIVES BUILT DURING 1913.

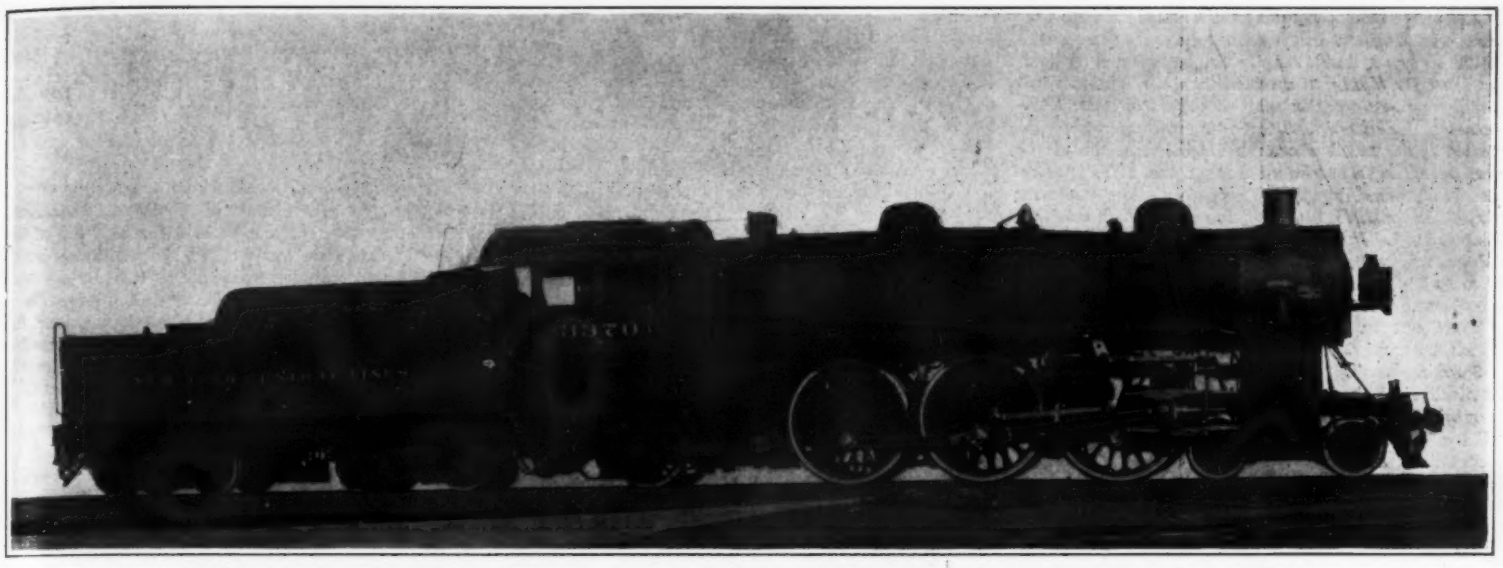
Design No.	Weight in Pounds.					Cylinders Diam. and Stroke, in.	Diam. Drivers, in.	Steam Pressure, lb.	Tractive Effort, lb.	Grate Area, sq. ft.	Heating Surface.				Tender.		Wheelbase.	
	Truck.	Drivers.	Average Per Axle.	Trailer.	Total.						Tubes, sq. ft.	Firebox, sq. ft.	Total, sq. ft.	Superheater, sq. ft.	Coal (tons).	Water (gal.).	Driving, ft. and in.	Engine, ft. and in.
1	27,500	245,000	61,250	49,500	322,000	27x30	63	190	56,100	59.6	4,494	218	4,740	1,084	12	7,500	16–6	36–1
2	30,500	240,500	60,125	49,000	320,000	28x30	63	180	57,200	70.4	3,266	290	3,591	846	16	10,000	16–6	35–3
3	29,000	238,200	59,550	52,100	319,300	28x30	63	180	56,500	63.0	4,017	230	4,276	898	16	9,000	17–0	35–2
4	37,000	228,200	57,050	52,600	318,400	27x30	62	190	56,000	62.0	4,547	274	4,821	1,101	12.5	8,000	16–6	35–2
5	28,000	233,500	58,375	45,500	307,000	28x30	63	185	58,700	57.1	4,095	224	4,339	953	15	8,500	16–6	34–11
6	28,000	227,500	56,875	46,500	302,000	27x32	61	170	55,300	63.1	3,939	230	4,198.6	890	13.3	8,275	17–6	36–5
7	27,000	214,500	53,625	46,000	287,500	26½x30	61	185	54,500	57.5	3,379	227	3,634	831	14	8,500	16–6	35–1
8	26,000	213,500	53,375	43,500	283,000	27x30	63	175	51,700	56.5	3,397.8	214.8	3,639.3	757.3	15	9,000	16–6	35–1
9	24,600	213,000	53,300	44,000	213,200	26x28	63	200	51,000	71.5	3,972	242	4,214	890	15	9,000	16–6	35–2
10	23,700	201,700	50,425	32,400	257,800	23½x32	63	180	42,900	49.3	3,403.4	200.3	3,603.7	566	16	7,000	16–6	35–5

ECONOMY AND CAPACITY.

Each year sees a more careful analysis of the service that the locomotives are to perform before the design is actually outlined, and while, so far, it has seemed advisable to design and build locomotives for the heaviest class of service on the road and to relegate the older power to the lighter service, a movement is beginning which will lead to the building of lighter locomotives suited for a particular class of service on branch lines or on certain divisions. The beginning of this movement is seen in the application of superheaters to lighter power as it goes through the shops for general repairs,



Mikado type locomotive, built for the Northern Pacific Railway.



Pacific type locomotive, built for N. Y. C. and H. R. Railroad. This locomotive hauls the "Twentieth Century Limited."

and the improvement of the valve gears and the installation of brick arches. It is probable that within the next year or so orders will be given for lighter locomotives which will have the benefit of the more advanced knowledge of design and arrangement, and thus will give the economy which is now obtained only from the newer and most powerful locomotives on the road.

In fact, the past four or five years have been devoted almost entirely to obtaining increased capacity. Advances in economical features, which have been so numerous, have all been applied to this end. The demands in this direction seem to be now pretty well taken care of and attention is beginning to be given to greater economy for the saving it gives, which means the same amount of power now obtained, if that is all that is needed or desired for the service, with a distinctly reduced fuel consumption and weight of locomotive.

The new Atlantic type of locomotive on the Pennsylvania, which is the most notable locomotive design of the year, is an indirect example of this, since it performs better service with a smaller consumption of fuel than a Pacific type which weighs about 60,000 pounds more. Some recent consolidations, where they have been designed to do and are doing the work that has previously required the 2-8-2 type, are also examples of the same tendency.

There has been, recently, a very general movement on all the more progressive roads to improve the older locomotives, so far as possible, and bring them up to nearly the state of efficiency and capacity possessed by the more recent designs. This is probably best marked by the many applications of superheaters to old locomotives as they pass through the shop for general repairs. This same movement has begun with stokers on the larger capacity locomotives. When superheaters are applied it is not infrequent to apply a new valve gear and to enlarge the cylinders somewhat.

This idea, in some cases, is even carried to a greater extent and consolidation locomotives are being entirely rebuilt and changed to the Mikado type. The most prominent example of this action has been on the New York Central, where a total of about 150 locomotives have been altered from 2-8-0 to the 2-8-2 type. The result has been an increase of fully 33 per cent in the capacity of the locomotive which has been obtained at a very reasonable cost.

TYPICAL PACIFIC TYPE LOCOMOTIVES BUILT DURING 1913.

Design No.	Weight in Pounds. Truck.	Drivers.	Average Per Axle.	Trailer.	Total.	Cylinders Diam. and Stroke, in.	Diam. Drivers, in.	Steam Pressure, lb.	Tractive Effort, lb.	Grate Area, sq. ft.	Heating Surface. Tubes, sq. ft.	Firebox, sq. ft.	Total, sq. ft.	Superheater, sq. ft.	Tender. Coal (tons).	Water (gal.).	Wheelbase. Driving, ft. and in.	Engine, ft. and in.
1	46,100	189,500	63,167	57,600	293,200	26x26	80	205	38,000	55.4	3,453	204	3,680	845	17.3	8,000	13–10	35–2½
2	46,500	185,500	61,833	56,000	288,000	25x28	73	200	40,500	94.8	3,579	239	3,857	821	10	9,000	13–0	34–10
3	47,500	186,500	62,167	50,000	284,000	25x28	69	200	43,100	58.0	3,727.6	199	3,954	867.8	14	8,000	13–0	33–10
4	51,300	179,900	59,967	50,800	282,000	27x28	73	185	43,500	59.6	3,535	220	3,786	879	14	8,000	13–0	34–1
5	53,000	174,500	58,167	54,000	281,500	25½x28	73	190	40,250	63.0	3,259.4	212.8	3,497.6	805	14	8,500	13–0	33–10
6	56,400	164,100	54,700	51,200	271,700	17½&29x28	73	210	34,000	57.6	3,233	181	3,444	619	12	9,000	13–8	35–1
7	50,000	172,000	57,333	49,000	271,000	23½x26	79	200	30,900	56.5	3,192.9	204	3,424	774	12	7,500	14–0	36–6
8	49,600	165,500	55,167	44,700	259,800	25x28	72	180	37,000	66.7	3,553	241	3,823	842	14	8,500	13–0	34–1
9	49,000	154,000	51,333	48,500	251,500	24x28	73	200	37,600	53.2	3,092	188	3,309.3	780	13	6,000	14–1	34–5½
10	49,300	159,200	53,067	40,100	248,600	24x28	76	185	33,500	56.5	2,359	185	2,567	587	16	7,000	13–2	34–3½

STANDARDIZATION.

Extension of the practice of standardizing many parts of the locomotive, particularly those requiring frequent repairs or renewal, is general. Even the practice of standardizing whole locomotives so as to greatly reduce the number of classes in service, with an accompanying large improvement in the maintenance account and in the condition of operation, is found on the more progressive roads.

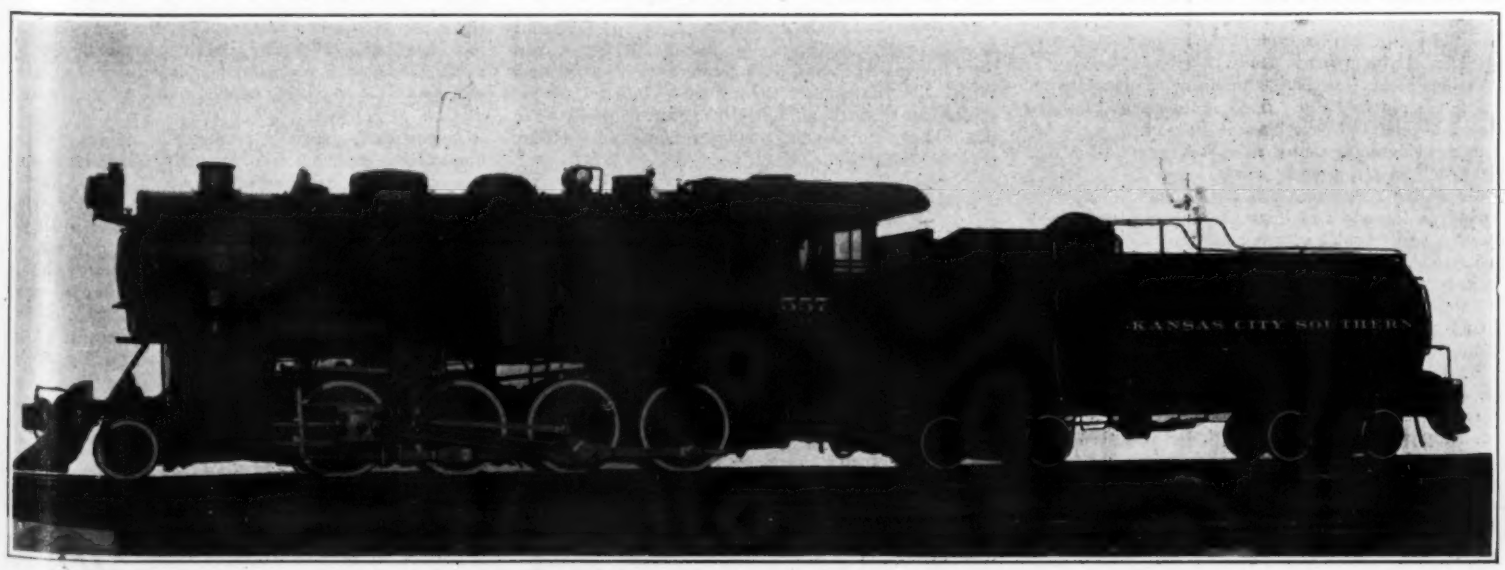
H. H. Vaughan, assistant to the vice-president, Canadian Pacific, indicated the advantages of fully standardized locomotives at a meeting of the American Society of Mechanical Engineers to be: Standard locomotives can be transferred from one part of the road to another without a large storehouse stock; continued construction of the same locomotives reduces the cost of building as well as of the later repairs; it is possible to effect desirable variations in design much better than can be done when classes differ. It was also pointed out that the time for standardization is before the locomotives are built and not after they are running.

There has not been so great a tendency toward standard classes as appears in respect to standard parts. In a number of cases new locomotives have been built which required little more than a new design of boiler, frames and cylinders.

BOILERS ARE BETTER PROPORTIONED.

While each and every part of the locomotive has been subject to careful scrutiny and decided improvement, the boiler has been the point of most searching investigation and greatest advance. The goal of boiler designers is to obtain the largest number of pounds of steam to each pound of metal in the boiler. The various studies and experiments have clearly indicated the advantages of the use of a longer flameway between the fuel bed and the end of the tubes, giving an opportunity for completing the gas reaction before the products of combustion enter the flues.

Experiments at the locomotive testing plant at Altoona as reported to the Master Mechanics' Association, show that boilers with short tubes have a distinct advantage in increased activity of combustion and in the rapidity of evaporation, or free steaming, but at the same time they also have a slightly lower efficiency since



Consolidation type locomotive built for K. C. S. Railway.

they absorb less of the total heat available during the passage of the gases through the tubes. It thus seems that the most desirable length of tube depends on how much one is willing to sacrifice in boiler efficiency to obtain rapid evaporation with some loss of heat. Experiments indicated that the rate of evaporation increased as the tube is shortened until it reached a maximum at a length between 12½ feet and 14 feet; after that it decreased rapidly. This information, taken in conjunction with the results of the experiments made at Coatesville in June, 1912, showing the comparative value of firebox heating surface and tube heating surface have had a noticeable effect already in increasing the use of combustion chambers with shorter flues.

The Pennsylvania has adopted a length of 15 feet for 2-inch flues and a length of 19 feet for 2¼-inch flues.

Speaking on this subject before the American Society of Mechanical Engineers, F. F. Gaines, superintendent of motive power of the Central of Georgia, stated that: "The most radical improvement that can be made on locomotives, and one which will be rapidly developed, is the use of greater firebox volume and heating surface. This is readily obtained by using a suitable grate area and combustion chamber. In fact, from past experience it would not be surprising if ultimately a flue length of 16 feet would become a desirable maximum and the combustion chamber be substituted for the remaining distance." Experiments that have been made by Mr. Gaines with a type of combustion chamber developed by him indicate the truth of his assertion.

While no distinct movement toward reducing flue length to 16 feet can be discovered, there is a noticeable tendency to increase the firebox heating surface, and this is being done both by the addition of a circular combustion chamber and, where possible, by the use of a firebox arranged on the Gaines principle.

Brick arches, supported on arch tubes, are now in very general use on all classes of locomotives. An appreciation of the value of the heating surface in the arch tubes is becoming more apparent and the objections that had previously been made to them seem to have been entirely overcome.

Openings for the admission of air into the ash pan and through the grate are, in a few instances, being given the attention they deserve, and in recent designs, which follow the best practice, as large an air inlet as possible is given. The opening should be 50 per cent of the grate area, or more, if possible, on road engines. More study should be given this most important subject, and it is probable that the most marked advance in locomotive operation in the coming year will be along the lines of securing more perfect combustion.

Experiments with a powerful passenger locomotive at the Altoona testing plant early in the year indicated the importance of further study of the nozzle, stack and cylinder passages. This has already had its effect and the present practice is to place the nozzle as low as it is possible to get it. Where the boiler is large in diameter, the internal extension of the stack is universally used in order to obtain the required length. The use of nozzle tips in shapes other than round has shown a distinct improvement in the exhausting of locomotives under certain conditions. It appears that the proper selection of the shape of the nozzle tip and the use of tips other than round are of great value in compensation for a poor arrangement of exhaust passages which in some cases is unavoidable on account of the lack of room. These nozzles in some instances have shown a surprising reduction in the coal consumption and an increase in power in the cylinders.

The study given to this feature has also led to a better design of the exhaust passage in the cylinder itself, with a still further reduction in the back pressure.

Various arrangements of blowers or suction fans for giving the required draft through the tubes have not passed beyond the experimental stage, and there has been no evidence presented as to what practical advantages such an arrangement might have.

Circulation throughout the whole boiler is being improved as the effect of improper flue spacing, narrow passages and trapping of water near hot sheets is better understood. The value of the arch tubes as circulation improvers is but beginning to be appreciated.

LARGER CYLINDERS.

One of the changes in proportions which has been found advisable in order to obtain the full advantage of superheated steam, is the use of larger cylinders. At first this was accompanied by a reduction in the steam pressure and the increased size of the cylinders was simply to obtain the full power with the lower pressure. Lately, however, a tendency is noted toward using larger cylinders, even with the high pressures, and some of the more recent designs would, at first sight, seem to be considerably over-cylindered. Here again it is the results from the Altoona locomotive testing plant that have pointed to the best practice. The conclusions reported to the Master Mechanics' Association of tests on Atlantic and Pacific type locomotives stated that for maximum economy with superheated steam the maximum indicated horse-power should be developed at a cut-off not exceeding 30 per cent.

At the Traveling Engineers' Convention, in the discussion of the report on operating superheater locomotives, it appeared that the best practice, in the opinion of those discussing the paper, was to use a full throttle opening up to the point where the cut-off was 25 per cent, and if a longer cut-off than this is necessary the throttle should be partially closed in preference to lengthening the cut-off. This, of course, means larger diameter cylinders if the full power of the locomotive is to be developed.

Larger cylinders, if they were to be used with late cut-offs, would imply the necessity of larger steam and exhaust ports, and thus larger piston valves. Since, however, they are being used entirely with the idea of using the short cut-off and the period of admission of the steam is at a time when the piston is moving slowly, there has been no noticeable movement toward larger valves. In fact, the tendency is more toward an improvement in the valve gear to give a larger port opening for both admission and exhaust, which allows the use of even a smaller diameter of valve. On one road the 12-inch diameter piston valve is being used with superheated steam on practically all sizes of cylinders, and no trouble is found in holding up the steam pressure during the first 30 per cent of the stroke. While 16-inch diameter piston valves have been used in a few cases, the general tendency is toward a smaller diameter and a more careful design of the valve gear.

On the Norfolk & Western, the Hobart-Allfree cylinders which provide an auxiliary exhaust opening and a reduced back pressure are being used on all new simple locomotives and are being applied to the older power as it requires new cylinders.

VALVE GEAR.

While the Walschaert type of valve gear is used on a very large majority of the locomotives, including all types, the Baker valve gear has been applied in a number of cases and at the present time there are about 2,000 locomotives operating in the country with this type of gear. New arrangements of valve gear seem to be attracting the attention of designers, and two or three original constructions have appeared during the year, but so far are only in experimental service.

The improvements in the Walschaert gear have all been along the lines of the use of better materials and thus of lighter parts, and the more rigid support of the valve-stem crosshead. The screw reverse gear has met with quite general favor and is being applied to many of the larger types of simple locomotives. On Mallet engines and some of the very large examples of the Mikado and Santa Fé types, power reverse gears have also been applied. A screw reverse was applied to some switching locomotives on the Illinois Central early in the year, and it is reported to be a satisfactory arrangement for this service when compared with the usual hand-operated lever arrangement.

On the Philadelphia & Reading a new arrangement of reverse gear which combines both the screw and lever designs was applied to an inspection locomotive. With this construction the complete reversal of the engine can be made promptly by means of the lever in the ordinary manner and the adjustments of cut-off are made by the screw.

USE OF ALLOY STEELS.

Alloy steels are being more widely used for many of the locomotive parts. In most cases the heat-treated steel is employed and very excellent results are reported. In a few cases a considerable reduction of section and of weight has followed the use of this improved material. More generally, however, the greater strength has been used for the purpose of reducing the unit fiber stress and thus increasing the reliability of the parts. The Pennsylvania allows 25 per cent higher stress in piston rods and pistons when heat-treated steel is used. This followed tests which showed the elastic limit of the material employed to be 50 per cent greater than the non-treated steel.

The alloy most generally employed has been a chrome vanadium. The number of parts of this material applied during the year to locomotives is given in the table at head of third column.

The frames are simply annealed, but all other parts are heat-treated.

STOKERS.

During the past year the service of the stokers previously applied and of the large number placed in service during the year, prove that this device has passed the experimental stage. Thus, after 25 or 30 years of experiment, the stoker has reached the position of reliability and serviceability which allows it to be accepted with confidence for use on the larger sizes of locomotives. This is probably as important a development as has occurred this year since it removes one of the greatest limitations in the way of further increase in the size of locomotives. The service results of the stoker indicate that the capacity of the locomotive as to maximum tonnage and speed will be increased by it in much the same way as has occurred by the application of the superheater.

	Number of Engines.	Number of Parts.
Axles	466	1,277
Crank pins	188	580
Piston rods	69	138
Main rods	347	734
Side rods	354	1,840
Springs (engine and tender)	306	...
Frames	776	1,592
Engine truck axles	62	62
Wheels	...	700
Tires	...	1,000

The overfeed or scatter type stoker is the more popular, although applications of the underfeed or Crawford design continue to be made, principally by the Pennsylvania Lines west of Pittsburgh.

Experience with stokers in comparatively large numbers on a single division or on a single road show that the cost of maintenance is low. The reports do not indicate, however, that there is any noticeable saving in coal by the use of stokers, but there is a considerable increase in the capacity of the locomotive in practically every case. Further advantage, particularly in connection with the underfeed design, is the elimination of the smoke which makes it of especial value for use on switching locomotives.

The Street stoker has received the widest application, and is now in use on 13 railroads which together have 365 stokers in regular operation and 69 on order. Reports from one of the roads using a large number of these stokers show that the maintenance is less than 0.5 cent a locomotive mile. In another case where there are 85 Street stokers in operation the reports show 50,000 locomotive miles for each stoker delay of any character. There are 293 Crawford underfeed stokers in use. This type is showing a satisfactory service both in reliability and cost of maintenance.

In addition to above-mentioned designs there is a single stoker of the Hanna type in use on the Carolina, Clinchfield & Ohio which has been in service for over three years. About three months ago an improved design of Hanna stoker was installed on the same road. Both machines are now operating with complete satisfaction.

Two new designs of stoker have appeared during the year, both being of the overfeed or scatter type. These are the Standard stoker which is now undergoing tests on the New York Central Lines, and the Gee stoker, which is in experimental use on the Pennsylvania. Experience with the former covering six months has led to the decision to make further experimental applications, and it is now being applied to a 2-6-6-2 type locomotive.

In general, the effect of the success of stokers has been a relief from the handicap of having to consider the stoking capacity of the fireman on very large locomotive units, a tendency to somewhat enlarge the size of cylinders on moderately large units and an increase in the tonnage rating of stoker locomotives due to the assurance of full steam pressure throughout the length of the run. In addition to the economies offered by improved operating conditions, a material saving in the cost of fuel has been obtained in a number of cases because of the ability to use a poorer and lower priced quality of coal with stokers.

Stokers have so far been applied almost entirely to freight locomotives, since it is here that the increased capacity is particularly desired. It is also in freight service that the fatigue of the firemen at the end of a long run is most noticeable in its effect on the capacity of the engine.

FEW COMPOUNDS BUILT.

Except on articulated types of locomotives, there appears no inclination to use compound cylinders. A very noticeable exception to this general opinion is found on the Atchison, Topeka & Santa Fé, where balanced compound Pacific type passenger locomotives

TYPICAL CONSOLIDATION LOCOMOTIVES BUILT DURING 1913.

Design No.	Weight in Pounds.				Cylinders Diam. and Stroke, in.	Diam. Drivers, in.	Steam Pressure, lb.	Tractive Effort, lb.	Grate Area, sq. ft.	Heating Surface.				Tender.		Wheelbase.	
	Truck.	Drivers.	Average Per Axle.	Total.						Tubes, sq. ft.	Firebox, sq. ft.	Total, sq. ft.	Superheater, sq. ft.	Coal (tons).	Water (gal.).	Driving, ft. and in.	Engine, ft. and in.
1	30,500	236,000	59,000	266,500	26x30	57	185	55,900	66.75	3,293.4	223.7	3,517.1	774	15	9,000	17–0	27–0
2	25,500	230,500	57,625	256,000	25x30	57	185	51,750	99.85	2,072.1	256.6	3,098.2	622.5	14	9,000	17–0	26–1
3	30,000	224,000	56,000	254,000	26x30	56	175	53,900	62.5	2,828.4	198.2	3,026.6	695.7	17	9,000	17–0	26–10
4	24,940	186,060	46,513	211,000	24x30	61	180	43,000	53.4	2,185	178.0	2,392.0	522	12	7,300	17–0	26–0

continue to be built. This company has had a long and extensive experience with balanced compound locomotives of the Atlantic, Prairie and Pacific types for passenger service, the earlier ones being with saturated steam and the later additions of the Pacific type having superheaters.

PENNSYLVANIA ATLANTIC TYPE.

Because of its exceptional facilities for obtaining accurate information on the effect of the various detail features of design, and a broad-minded policy of the management in respect to the activities of the motive power department, it is not surprising that it is on the Pennsylvania Railroad that the greatest progress and most advanced position in locomotive design is found. This is well illustrated by the design of Atlantic type locomotive that has been perfected by this company during the past year.

This locomotive, on one district of the road which includes a very heavy grade, is pulling trains containing six all-steel passenger coaches, while a powerful Pacific type that has a total weight of 60,000 pounds more than the Atlantic is able to handle but five cars on the same schedule. Furthermore, the same class of locomotive is successfully pulling trains of thirteen steel cars weighing up to 984 tons, between Manhattan Transfer, N. J., and Philadelphia, Pa., on schedules which require a sustained speed of 60 miles an hour for long distances.

No one feature of the design can be held as being principally responsible for this remarkably successful service. Boiler capacity, of course, is the absolutely essential feature for sustained power at high speeds, and these engines exceed all previous attempts for a two-coupled locomotive in this respect. The powerful boiler necessarily means heavy weight, and here again have the records been broken. The weight on each of the drivers approximates 67,000 pounds, and the total weight of the locomotive is 240,000 pounds.

This apparently excessive weight on drivers is permitted because the dynamic augment due to the counterbalance at a speed of 70 miles an hour is less than 30 per cent of the static weight on drivers. As a result these locomotives do not deliver as heavy a blow on the rail nor do they have as bad an effect on the track, so far as strain is concerned, as the majority of passenger locomotives which have a weight on drivers from 10,000 to 12,000 pounds less per axle.

This result has been obtained only by the utmost care in the design of the reciprocating parts to obtain the minimum weight with the great strength required by the amount of power that is transmitted by a 23½-inch diameter cylinder with 205-pound steam pressure. What has been accomplished in this respect is probably best illustrated by a statement of the weights of the various reciprocating parts of this locomotive. The 23½-inch diameter piston with piston rod key and shoe complete weighs 408½ pounds. The crosshead and wrist pin complete weigh 312 pounds, and the crosshead end of the main rod weighs 279½ pounds. This gives a total of 1,000 pounds weight of reciprocating parts on each side of the locomotive. The same care and refinement was also given to the valve and gear, and the main valve, which is a hollow inside admission 12-inch piston type, weighs but 119 pounds. The valve stem crosshead and pin weigh but 43½ pounds, and the lap and lead lever 39½ pounds.

Success in the effort to obtain the minimum weight of these parts is due to two things. First, the most careful analysis of the stresses and a determination of the best form of construction to properly transmit them. Second, the use of the very best quality of heat-treated steel where it possessed any advantage. The piston heads are drop forgings and are Z-shape in section. The piston rods are hollow and are of the very best quality of material, heat treated. The main and side rods are also heat-treated steel, and the steel casting forming the crosshead is remarkably small and light.

After the very low percentage of dynamic effect of the counterbalance, probably the next most important feature of the design and one which is unique for this type of locomotive is the method of equalization, whereby the four-wheeled front engine truck is equalized with the front pair of drivers and the back pair of drivers are equalized with the trailer truck only. It is believed that this is the first instance of equalizing an Atlantic type locomotive in this manner and the result has been highly satisfactory.

The design of the boiler is as interesting as the other features and is based on the principles that have been developed by the work on the locomotive testing plant. No attempt can be made here to give a full description of the boiler, and it is sufficient to state that it is of the Belpaire type which is standard on the Pennsylvania, has an outside diameter of 78½ inches at the front end and 2-inch flues 15 feet in length. The grate area is slightly in excess of 55 square feet, and a 36-unit Schmidt design superheater has been applied.

The advantages of the screw reverse gear are indicated by the fact that it has been used on this locomotive where the weight of the valve gear and parts is very light and it is not actually required on that account.

Some of the general dimensions of the class of locomotives of this type now being built are as follows:

Tractive effort	29,427 lb.
Total weight	240,000 lb.
Weight on drivers	133,100 lb.
Weight on leading truck	55,000 lb.
Weight on trailing truck	51,900 lb.
Weight of engine and tender in working order	398,000 lb.
Wheel base, driving	7 ft. 5 in.
Wheel base, total	29 ft. 7½ in.
Wheel base, engine and tender	63 ft. 10½ in.
Diameter of driving wheels	80 in.
Diameter engine truck wheels	36 in.
Diameter tender truck wheels	
Cylinders, diameter and stroke	23½ x 26 in.
Diameter piston valve	12 in.
Valve travel	7 in.
Steam lap	1 5/16 in.
Lead	
Steam pressure	205 lb.
Outside diameter, front ring of boiler	78½ in.
Firebox, length and width	72 in. x 110¼ in.
Tubes, number and outside diameter	242—2 in.
Flues, number and outside diameter	36—5 3/8 in.
Tubes and flues, length	180 in.
Heating surface, tubes	2,660.5 sq. ft.
Heating surface, firebox	195.7 sq. ft.
Superheater, heating surface	721 sq. ft.
Heating surface, total	2,856.2 sq. ft.
Grate area	55.13 sq. ft.
Tender, water capacity	7,000 gal.
Tender, coal capacity	13 tons

POWERFUL CONSOLIDATION.

Another interesting locomotive design which typifies the present progress is a consolidation type for the Wheeling & Lake Erie, designed and built by the American Locomotive Company. This design illustrates what can be accomplished with some of the older types of locomotives. It was only about a year ago that the general opinion prevailed that the consolidation type was at the point of becoming obsolete for new locomotives, and that the Mikado would entirely replace it. There were good grounds for this impression, for, with the exception of the Pennsylvania, no road had made any important improvement in this type for over ten years. This locomotive, however, proves the fallacy of the conclusion, and within the speed limits of a 57-inch diameter driver it has distinct advantages over a Mikado type. It delivers a pound of maximum tractive effort for each 4.77 pounds total weight of locomotive, and gives one square foot of equivalent heating surface for each 57 pounds total weight of locomotive.

In this connection it is interesting to note that the consolidation type locomotive is being more generally used in all sizes than was the case a couple of years ago. In the present year the total orders for this type exceeded 700, while the orders for Mikado locomotives were somewhat less. There were about 435 locomotives of the 2-8-0 type ordered by the Pennsylvania alone during the year.

The Moving Picture in the Machine Tool Business*

Its Application to be Made of Increasing Value to the Industry

By Chester L. Lucas

THE moving picture as an entertainer is rapidly making room for the moving picture as an instructor. This has been much in evidence recently in the scientific films which have been shown to illustrate plant life, biology, laws of physics and similar subjects. Another phase of moving picture activities was manifested in motion study for "scientific management," and a still later one in the moving picture as an aid to the machine tool builder in handling factory problems and selling campaigns. Several examples of the use of moving pictures in aiding the salesman will be cited in this article and suggestions offered whereby the application of the moving picture may be made of greater value in the machine tool industry.

Primarily, the service which the moving picture can render to the machine builder is instruction in the factory or the selling field. Suppose, for instance, a manufacturer of an intricate machine had trouble in getting his machines properly set up and started after they had been taken down at the factory for shipment to distant points. Although drawings and printed instructions were sent with each machine, there was often difficulty in setting up and starting. This manufacturer could have a moving picture film made to show just how the machine should be assembled and operated. It could show the sequence in which the members should be put together, graphically illustrate the important parts to be most carefully assembled, and in fact showing the building up of the machine from the time it left the crate to the completed stage ready for operation. No amount of verbal or written instruction could make this process as clear as a picture could, and, moreover, the entire process of assembling the machine, unless extraordinarily long, could be carried through in a thousand feet of film, requiring about twenty minutes to show. The question will be raised as to how the man who is to set up the machine is to see the film in a case like this. If the machine is going to a point not far distant, the machine manufacturer can arrange to have the men who are to set it up come to his factory and see the film on a screen and listen at the same time to instructions. It would often be the case, however, that the film would be most valuable when the machine is going so far away that verbal instruction in the factory is impracticable. In such cases the erectors can have the film shown in the nearest moving picture theater in the morning hours and study it at leisure. It seems a safe prediction, however, to say that not many years will elapse before a small moving picture machine will be as essential a part of a manufacturing plant's equipment as the camera is at the present time. Many colleges and schools are now using moving picture machines for instruction.

Depicting mechanical movements is an interesting field for the moving picture. It is practicable to slow down or speed up any movement when making a moving picture film. Suppose, for instance, the operation of a very slowly moving piece of mechanism is to be shown. In this case the moving picture camera is set up and the operating crank is turned very slowly so as to take as few pictures as possible and still show continuous movement. This is the method employed in making botanical pictures showing the growth of a plant—a process normally requiring several weeks being reproduced in a few minutes. To get this effect, the photographs are taken at the rate of one every eight hours instead of sixteen every second as for ordinary moving pictures.

The value of this possibility to the mechanical public is illustrated in an automatic machine that was made in Brooklyn, N. Y. This machine made one revolution every thirty-one minutes, and as it was desired to show its operation, a moving picture was made, taking the pictures so slowly that the full revolution of the machine could be thrown on the screen in a few minutes. Conversely, a mechanism operating at high speed may be taken by accelerating the picture-taking camera speed if it is desired to show it operating at a slower speed. Then when the film is projected at the normal rate of sixteen pictures per second, the speed can be made apparently slow. Thus the movement of any kind of mechanism can be graphically illustrated to students or apprentices, who perhaps could not grasp the operation if it were running at full speed. Especially is this true of spring-actuated mechanism, such as that employed in some adding machines in which analysis of the movements of the parts is difficult. The National Cash Register Company uses moving pictures to instruct repair men as well as salesmen in the manipulation of the different parts of the mechanism.

Films for instruction purposes along mechanical lines can be used at much less expense than that of keeping and operating the mechanism itself. Thomas A. Edison proposes to demonstrate the elementary laws of physics to school children who would have great difficulty in understanding them from textbook descriptions, by making moving pictures of pumps having glass working parts. If the operating parts of any mechanism are inaccessible to observe or study, they are the parts that should be most clearly shown. Moving pictures of such sections make the operation of the machine clearly understood.

An instance of the aid of the moving picture to the scientist and teacher in the study of gyroscopic motion may well be cited. Why does a hollow rubber ball balance itself so perfectly at the top of a jet of water? By making moving pictures at high speed and projecting them upon the screen, the ball is shown to acquire a gyroscopic motion at the top of the column of water, tending to keep it from going off at the side. In the comparatively slowly operated pictures the water takes on the appearance of molasses, and its motion seems sluggish in comparison with the rotation of the ball. The experiment has been carried still further by shooting the column of water with a rifle bullet. When

*Reproduced from *Machinery*.

this is shown on the screen, the effect of the bullet is to shatter the column from top to bottom, after which it is been to pull itself together and finally return to the former position.

Another case where the moving picture will undoubtedly prove of value as an instructor is in showing the operation of automatic machinery that has been built and shipped perhaps years before. A concern building automatic machinery might have produced a machine such as that illustrated by the film from which the print in Fig. 6 was made, the mechanism of which was especially complex. Suppose, after the machine had been built for several years, it was destroyed by fire. If a film showing the operation of this machine was at hand, it should facilitate the building of a duplicate machine by a new set of men, for even though drawings are accessible, there is often doubt about operating points that a moving picture would clear up.

RECENT DEVELOPMENTS IN HIGH-SPEED PICTURES.

Pathe Frères are undoubtedly among the leaders in producing scientific films, and it is through their courtesy that much of this information and some of the views were obtained. They have recently developed a high frequency spark apparatus used for taking pictures of rapidly moving objects. These pictures, of course, must be taken in a dark room; the film operates continuously, that is, without the intermittent motion of the ordinary moving picture camera. The spark operates at the rate of 1,200 flashes per second and this number of exposures is made on the film. By this method, they have been able to record the path of a bullet shot at a clay pipe. By projecting the film at normal speed, the bullet could be followed slowly across the screen until it entered the clay pipe bowl. It seemed to remain within the bowl for a few seconds and then slowly, very slowly, the bowl dropped to pieces and the sections fell to the floor. Of course this film looked unnatural, but it showed the possibility of analyzing the action of rapidly moving objects.

Of course, there is hardly any need of mentioning the value of the moving picture as an aid in instructing apprentices and unskilled workmen in their duties. One does not have to draw on the imagination to a great extent to see the advantage of the moving pictures in instructing the apprentice as to the sequence of operations to follow in performing a given operation in the approved manner.

THE MOVING PICTURE AS AN AID TO THE SALESMAN.

Just as the highest type of technical advertising involves showing machine tools actually at work, so the great advantage of the moving picture lies in its ability to show to the prospective customer just what the advantages of the machine in operation are. A large steel company was particularly interested in securing foreign business. It wished to show foreign prospects the equipment of the plant, the large lathes, planers and the

Fig. 1.—Making a moving picture film in a machine shop.

magnitude with which the business was conducted. It was impossible to bring these men to the works, so the company decided to take the works to the men. Accordingly, moving picture films were made, showing panoramic views through the plant and detail views of some of the large machine operations. These films were sent to the company's foreign agents, who, through the aid of a projecting machine, showed them to the prospective customers. The views made such an impression that large orders from these foreign countries were soon received.

The educational film showing, for instance, the making of a typewriter or the building of an automobile is becoming quite common, and its value as an advertising attraction has been well demonstrated. Several large manufacturing companies are already exhibiting at conventions and exhibitions showing the manufacture of their product.

Small portable projecting machines are coming to the front more rapidly than ever. One of the latest of these weighs but little more than a typewriter, and the turning of the crank also operates a magneto, thus generating electric light for illuminating the pictures. The machine is self-contained and, with its case, comprises a portable outfit which a salesman can easily take into the office of a prospective customer. Then, by drawing the shades, the moving pictures can be projected upon the blank wall to show the superintendent or manager just how the machine works. Of course, films would be selected to exploit some impressive job, showing the machine working at its full capacity, preferably on the class of work done by the prospect. The salesman can demonstrate exactly how the different movements are secured. The explanation of an automatic feed throw-off, or the action of a cam movement, could be readily made in a demonstration of this sort.

Many times a salesman would like to take a prospective customer to a plant to show one of his firm's machines in action. This is sometimes difficult to accomplish; days when the machine would be working at its best are comparatively few. Even should a time be arranged for showing the prospect the machine at work, the surrounding conditions might detract from the effectiveness of the demonstration, and if the shop were far away from the prospective customer's location, he might be unwilling to go there. With a good film of his machine to show, however, a salesman could take his prospect, or several of them, to the nearest moving picture theater, and for a small sum the proprietor would be glad to run the film for him during the morning hours. There is scarcely a town of 500 inhabitants or more but what has its moving picture theater, and there is hardly one of the managers who would not gladly run special films during hours when the theater would otherwise be idle. Similarly, the morning hours of a theater could be utilized for instructing the apprentices of nearby factories.

The Motionscope Company, of Indianapolis, Ind., makes a portable outfit by means of which a salesman can show his prospect the film in his own factory or even in the salesman's room at the hotel. This machine is illustrated in Fig. 4, and is adjustable for any electric light current whether alternating or direct, 110 or 220 volts. Less than five minutes is required to put it in operation and it will show a picture as large as six feet wide. This machine may also be used for showing slides or stereopticon views. Equipped with a 24-inch screen, the outfit is contained in a case measuring 24 by 14 by 9 inches, and weighs approximately 35 pounds. Fig. 3 shows the way in which the machine is used in an office. The operation of any machine tool can be dem-

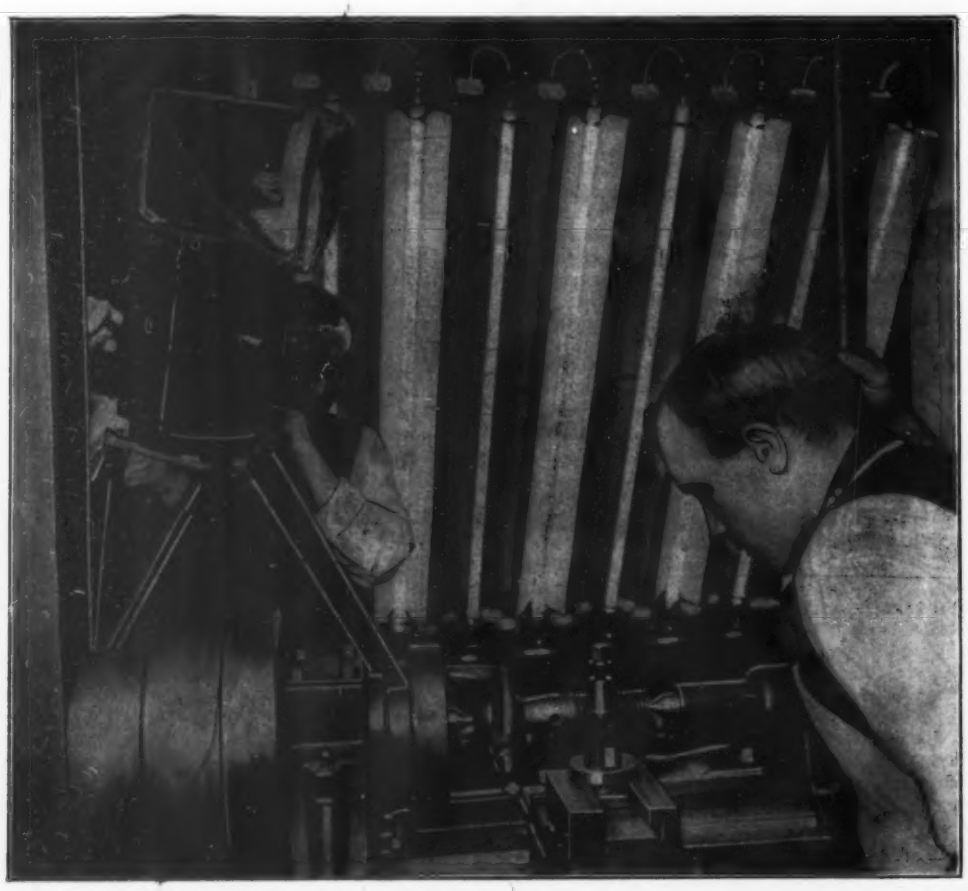


Fig. 2.—The way the camera and lamps are arranged to make a detail film.

Fig. 3.—An instructor showing the operation of mechanism.

onstrated with such an outfit. The salesman can stop at any point and dwell upon particular features that the view shows and he is not at the disadvantage of putting forth his argument in the midst of a noisy shop where much of his selling powers would be wasted. The film, of course, would show the machine working at its best, for moving pictures are not made on the "off days" of the machine.

In instances where it would be impracticable to send a salesman because of the distance, a film could be sent by registered mail to a prospective customer a thousand miles away. Arrangements could be made with a local moving picture house to show the film, this perhaps making the closing argument in a chain of selling correspondence.

The cost of making a mechanical moving picture film of one thousand feet or more in length is about one dollar per foot. This includes the services of the men who go to the plant, arrange the lighting and apparatus and make the film. When this film is once made, however, copies can be made at the cost of fifteen cents a foot. Should a sales manager decide to equip six of his salesmen with projecting machines and films to show a machine tool, it could be done at the rate of about thirty cents per foot, figuring the cost of the first film at one dollar per foot and the additional five at fifteen cents per foot.

MAKING A MECHANICAL MOVING PICTURE FILM.

The requirements for making a moving picture film of a machine tool operation are comparatively simple. The film manufacturer understands how to get proper exhibition effects of any class of mechanism, and the lighting requirements are easily taken care of. It is seldom that a machine tool operation can be photographed without the aid of artificial light. Cooper-Hewitt electric lights are used to a large extent by the moving picture film men, and by using enough of these lights in conjunction with arc lamps it is possible to take views.

In order to show the exact method in which a mechanical moving picture of a machine tool operation is made, the views in Figs. 1 and 2 are reproduced. This shows the method of procedure in making a picture to demonstrate the operation of cutting a thread upon a jack screw. The lathe used was not equipped with a thread-cutting attachment as it was desired to have the operation explained on the ordinary type of lathe.

The lathe is shown set up for a thread-cutting operation, and as the object of the part of the film being made in Fig. 1 is to secure a general effect, showing the position of the operator and the manipulation of the lathe, the moving picture camera is situated at the back of the lathe. Cooper-Hewitt lamps are used, there being in this case three banks, each of which has eight tubes having 800 candle-power each; thus in each bank there is 6,400 candle-power or a total of 19,200 candle-power in all. The positions of the banks of light upon the standards may be changed at will by raising, lowering or tilting. All being in readiness, the machine tool is operated in a natural manner, and the camera man turns his film at the rate of sixty turns per minute, making exposures at the rate of sixteen per second. These exposures, of course, show the operator and machine in ever-changing positions, each of which represents conditions at intervals of 1/16 second; thus the fifteen views shown in the strip of film in Fig. 5 represent the 15/16 second time required for the lathe man to drop his hand from the shipper rod down to the cross-feed screw on the carriage.

To make the thread-cutting film complete, a section would necessarily show the selection of the change gears and method of setting up the work. The setting in of the cross-slide after the successive cuts could also be graphically shown. In fact, a film for teaching such an operation should show enlarged views of all of the important phases of the work. In making such detail sections of a moving picture, the camera is set up as illustrated in Fig. 2. In this view, but one bank of lights is required, raising and inclining it so the rays will fall directly upon the work. The camera has also been raised and is pointed down upon the top of the screw thread and tool so as to show the actual cutting operation, the form of chip turned off, and the comparative speed of the work. The object of this feature of the film is to show the reversing operation necessary at the end of the thread. The thread tool is nearing the end of the cut and the operator, with his hand upon the shipper, is about to reverse the traverse of the carriage. This section of the film would be particularly valuable in instructing the novice in properly withdrawing the tool and reversing the lathe at the end of a thread cut.

Fig. 5.—Section of film illustrating operation of lathe man dropping his hand.

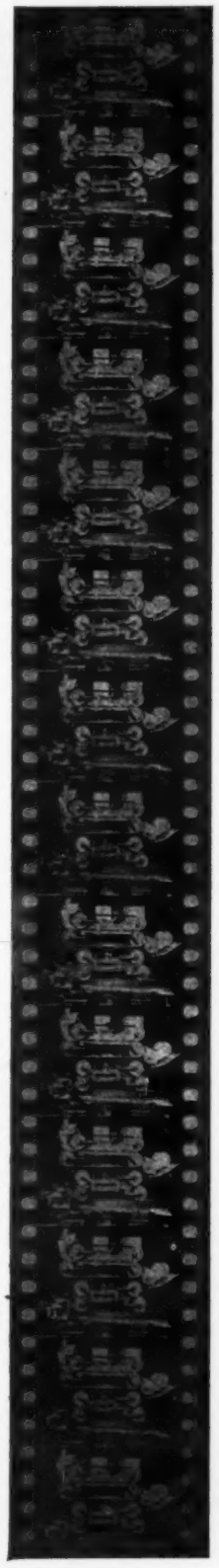


Fig. 6.—Section of film showing operation of automatic machine.

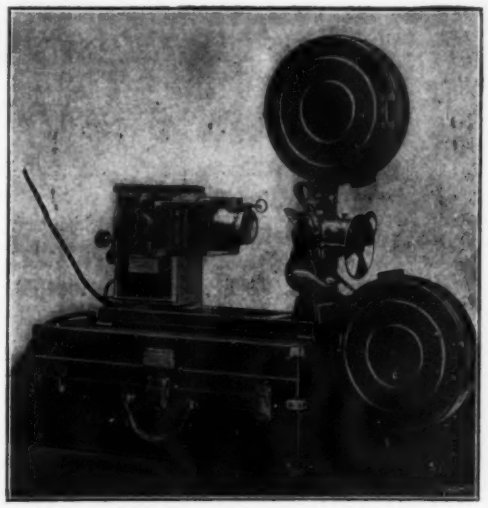


Fig. 4.—How the camera is set up.

Credit is due Pathe Frères, Jersey City, N. J., and the Harold Ives Company, 1 Madison Square, New York city, makers of industrial films, for assistance in preparing this article.

Coloring the Wood of Growing Trees

THE darker shades in wood are so much more highly prized for ornamental purposes that it has long been a practice to stain artificially the lighter woods, such as birch and soft pine. Some years ago a new method of coloring wood was introduced approximating natural processes more nearly and giving the effect of "aging" throughout the mass of the wood, the best results being obtained in wood containing tannin. Thus ordinary oak under certain conditions can be made to assume the rich dark hue characteristic of swamp oak or black oak. The shade, however, is variable, since the constituent elements of the wood itself largely determine the results obtained, wood which contain tannin yielding different results from those lacking this substance and resinous varying from non-resinous woods.

These facts have raised the question whether the constituents of the *living* wood, i. e., of the growing timber, could not be altered in some manner. The idea was not the production of variegated wood, but the introduction into the living tree of some substance which would so penetrate the wood and produce such chemical alteration that proper treatment subsequently would give to the lumber a typical tone throughout its mass.

For example, if it were possible to impregnate such tannin-free woods as birch and maple with a tannin solution during growth it would later be a very easy matter to give these woods a rich dark tint similar to that of the oak (which is rich in tannin) by means of treating it with ammonia under pressure.

According to *Die Naturwissenschaften* experiments in this direction were made as early as 1839, but without much success. Recently, however, Dr. Kleinstück has obtained valuable results from experiments which he describes in the *Zeitschrift fur angewandte Chemie*. He found that the wood was most successfully impregnated when the bore-hole passed entirely through the trunk of the tree. One end of this channel is stopped with cork, and into the other a tube is inserted through which the impregnating fluid flows from a suitable container. In large trees a whole system of bores is made.

In the first series of experiments use was made of aniline dyes, which must be soluble in water, easily diffusible and light-fast.

Thus malachite green and methylene blue were found to color birch evenly and uniformly, while eosin merely veined the wood with red.

Secondly, substances were employed which give typical reactions with the lignin of the wood, e. g., paraphenylendiamin and anilin hydrochlorate. By the use of a 1 per cent solution of the first salt a birch tree was thoroughly colored over night, and after a few days the dark sheen of the leaves had been so deepened that from a distance the tree looked like a copper-beech.

The power of absorption is found to be very great. Thus, a fir drank up 10 liters of salt solution in two days. In a third series substances were experimented with, which, like tannin, gave the lumber a definite tone upon subsequent treatment.

Finally, artificial pressure from without was tried, but this failed to yield satisfactory results.

There are several bands of the Persian fat-tailed sheep on the national forests of southern Utah. The large fat tail sometimes weighs as much as forty pounds, and, like the hump on the camel, is a reserve supply of nourishment when food is lacking.

The Permanent Fireproofing of Cotton Goods*

An Industry on Which Upwards of 10,000 Tests Were Made to Solve the Problem

By Prof. William Henry Perkin

AMONG the problems of technical interest which I have worked at during many years, one of special importance is the permanent fireproofing of cotton goods and other inflammable materials. The problem of the prevention of fire has always been one of the most pressing and at the same time one of the most difficult and perplexing with which mankind has had to deal. In very early times wooden houses caught fire and were burnt down, and it is said that the Romans attempted to render wood fireproof by dipping it in a bath made of vinegar and powdered clay.

This treatment, so strongly reminiscent of processes employed many years afterward, would no doubt be effective in rendering the wood less liable to inflame, but it can hardly have had wide application because vinegar, in those days, was not easily obtained in quantity and was consequently an expensive substance. I have made a search in a number of old books with the object of discovering some other of the actual methods used in early times in connection with fireproofing and the first pamphlet on the subject which I have been able to find dates from 1638, when Nikolas Sabattini published a remarkable paper in which he discussed the need of reform in the administration and construction of the theaters in Italy and pointed out the danger, which is always present, of fire breaking out on the stage, not only owing to the inflammable nature of the wood employed in the construction of the theater and for the decorations and scenery, but also on account of the inflammability of the cotton material used in the scenery and for the dresses of the players.

He recommends, as a safeguard, that the color used in painting the theater and scenery should be mixed with clay and gypsum, but says nothing about the fireproofing of the dresses.

At a considerably later date—in 1735—Wild suggested a mixture of alum, borax and sulphuric acid for the same purpose, and, in 1740, Fagot, in a paper read before the Academy in Stockholm, recommended a mixture of alum and green vitriol whereas, in the Dictionnaire de l'Industrie published in the year 1786, there is a paragraph in which it is stated that a mixture of alum, green vitriol and salt is effective in making wood and other material fireproof.

After the disastrous fire in Munich, on the 14th of January, 1823, which completely destroyed the Hof and National Theater, a large number of experiments were made with the result that the wood used in the construction of the roof and other parts of the new theater was painted with several coats of sodium silicate and chalk.

A coating of this kind lasts for many years and, although it does not render the wood absolutely non-inflammable, it has at least this value that the incipient fire, which, as a rule, begins in quite a small way, meets with resistance at the outset, progresses but slowly and is easily extinguished.

At a somewhat later date, it was discovered that wood saturated with other salts such as, for example, copper sulphate or ammonium phosphate, acquires the property of resisting flame, but of all the salts, zinc chloride seems to be the most efficient for this purpose.

In the first place, zinc chloride has great affinity for, and, therefore, attaches itself readily to, woody fiber, and fibers of all kinds and material saturated with a solution of this salt and then dried are practically non-inflammable. This salt has also this valuable property that it is a powerful antiseptic and therefore very suitable for fireproofing the wood used in the construction of hospitals and other public institutions of a similar nature.

But I do not propose to address you this afternoon at any length on the subject of the fireproofing of wood and other building materials, a subject on which I have made comparatively few experiments and of which I, therefore, have little practical knowledge.

What I wish to discuss, and I hope that the subject will prove interesting to you all, is the problem of the permanent fireproofing of wearing materials and especially of cotton and cotton goods, and by permanent fireproofing I mean protection which is not removed when the materials are subjected to the ordinary domestic wash.

Many disastrous accidents are on record which have been brought about by clothing catching fire: sometimes it is the case of a child whose garments have come in contact with a spark or lighted match and sometimes disasters of much greater magnitude have resulted from the ignition of costumes made of tow or other inflammable material on the occasion of charity entertainments or fancy dress balls.

It has long been recognized that impregnation with certain salts very much reduces and indeed may entirely destroy the liability of cotton goods to inflame and, of these fireproofing agents, I may perhaps be allowed to refer to a few only of the better known and more efficient. If a garment, after washing in the ordinary way, is rinsed in a solution containing alum or is starched with a starch containing a proportion of alum, the material, after drying, shows a marked reluctance to ignite, but this treatment has many drawbacks. In the first place it makes the material very dusty, and secondly, the fireproofing is only of a temporary nature since it is at once removed by contact with water and the process must therefore be repeated every time the goods are washed. I can easily demonstrate this and, in these and all my other experiments, I purposely take only very narrow strips in order that any smoke produced may not cause inconvenience in this hall. Another solution which has been strongly recommended for the same purpose is made up with 3 parts of ammonium phosphate, 2 parts of ammonium chloride and 1 part of ammonium sulphate in about 40 parts of water. If the material after washing is impregnated with this solution and dried, or if it is starched with starch made with the solution instead of with water, the dry material only ignites with difficulty, and as it does not dust and is not prejudicially affected in any other way, this process has been used with advantage not only in connection with wearing material but also for the fireproofing of lace curtains and other inflammable decorations. But in this case also, the fireproofing agents employed are all soluble in water and one washing is sufficient to remove them entirely, leaving the goods at least as inflammable as before. The process must therefore be repeated every time the goods are washed and this means expense which, in the long run, becomes considerable.

But a much more serious drawback to processes of this kind is the trouble they entail since, in order to fireproof the garment the washer-woman must have alongside the ordinary wash tub, a second tub containing the fireproofing solution and this complication, added to the expense of the salts, has been shown to be so serious that processes of this kind are quite impracticable, especially in the homes of the poor. Again, unless the materials or garments after washing, have been dried before immersion in the fireproofing solution, this solution can not be kept uniform since, each garment being wet when put in leaves the solution weaker than before and therefore of less protective value. To dry each garment between the washing and the fireproofing entails so much trouble and labor and expense that it would obviously prevent any general adoption of the practise. Although the substances I have mentioned and the salts of ammonium in particular, possess in a high degree the property of rendering material fireproof, there is one substance which confers the property of resisting fire to cotton goods in such a remarkable degree that it has long attracted attention and must be specially mentioned, and that is sodium tungstate.

A piece of muslin soaked in a weak solution of sodium tungstate and then dried is practically non-inflammable, but unfortunately this salt is again so excessively soluble in water that a mere rinsing in clean water is suficient to remove it completely and the fireproofing is lost. And this applies not only to sodium tungstate but also to all the other salts which have, from time to time, been recommended for fireproofing purposes; the result is not permanent because the proofing is at once removed when the goods are washed in the ordinary way.

The problem on which I was engaged for several years and which has now been successfully solved, in a very simple manner, was that of attempting to discover some process which not only made the goods non-inflammable but also *permanently* non-inflammable, and the researches on this subject were originally started in connection with flannelette, a material very largely and widely used for clothing, especially by the poorer classes, and one of the most, if not the most, inflammable of all cotton goods.

Flannelette may be briefly described as a kind of calico, the surface of one or both sides of which has been "carded" or "raised" into a nap, the result being that the surface of the calico becomes covered with a fluff of minute fibers somewhat resembling a thin layer of cotton wool. This effect is produced by subjecting the surface of the calico to the action of a series of revolving rollers covered with a vast number of small pieces of sharp steel wire, which tear up the surface, and the material is passed over these rollers over and over again until the required amount of nap has been raised. The result of this superficial covering of nap is—as everybody who has handled flannelette will know—a warm, pleasant and cosy feel, and this is no doubt due to a covering of air being imprisoned by the minute fibers thus producing a layer which acts as a non-conductor much in the same way as in the case of flannel.

In the first two samples in the little book which you each received as you entered the hall are calico and flannelette and you will notice at once the great difference in the feel between the comparatively hard flat surface of the calico and the raised surface of the flannelette.

Flannelette is indeed little, if at all, inferior to flannel as a non-conducting material and as it is very cheap and does not shrink in the wash, it has become very popular and is manufactured in enormous quantities and almost universally used for the clothing of children, especially in the homes of the poorer classes.

But it was not long before its increasing use showed unmistakably that it has one terrible drawback—the nap, which is its peculiar feature, makes it highly inflammable and much more so than the calico from which it was manufactured.

Flannelette is in fact, as I have already said, very much like calico on the surface of which a thin layer of cotton wool has been spread and this layer is, of course, highly inflammable.

I can easily demonstrate the difference in the inflammability of calico and flannelette by applying a light to strips of each, when it will be seen that while calico burns in the ordinary way, in the case of flannelette, the flame flashes over the whole surface of the fluffy cotton layer and travels with extraordinary rapidity.

It is, of course, this property which makes flannelette one of the most dangerous of materials for clothing purposes. The alarming frequency of deaths by burning due to the wearing of flannelette became common knowledge, the coroners all over Great Britain repeatedly called attention to the matter and by degrees the agitation against its use for clothing became so persistent that the Coroners' Committee of the Home Office was directed to inquire into the matter.

The committee recognized that while, to quote the words of their report, "We think the common opinion attributing to it (flannelette) a large share of the blame (of burning accidents) is not far wrong" that it was impossible to prohibit its use without causing great hardship, especially to the poor. Several years before this inquiry was held, one of the largest firms of flannelette manufacturers in Manchester, Messrs. Whipp Bros. and Tod, becoming alarmed at the frequent occurrence of fatal burning accidents and fearing lest these might lead to the prohibition of the sale of the material, came to me and asked whether I would undertake a series of experiments with the object of endeavoring to find a remedy for this state of things, and, after looking carefully into the matter, I consented to do what I could. That the problem was a difficult one from many points of view will be readily understood if I briefly state the conditions which had to be kept constantly in mind while the experiments were being carried on. A process to be successful must in the first place not damage the feel or durability of the cloth or cause it to go damp as so many chemicals do, and it must not make it dusty. It must not affect the colors or the design woven into the cloth or dyed or printed upon it; nothing (such as arsenic antimony, or lead) of a poisonous nature or in any way deleterious to the skin, may be used and the fireproofing must be permanent, that is to say, it must not be removed, even in the case of a garment which may possibly be washed fifty times or more. Furthermore, in order that it may have a wide application, the process must be cheap. What was really to be aimed at was to treat the flannelette in such a way that it acquired practically the properties of wool, which, for all ordinary purposes, may be taken as the standard of a safe material. Apart from the other conditions which I have laid down, when one considers the vigor with which the ordinary washer-woman scrubs garments with soap, not infrequently with the assistance of the scrubbing brush, and takes into account the wonderful mechanical appliances now so largely used for washing clothes with the least expenditure of time, it will not be thought surprising that the discovery of a process of fireproofing sufficiently permanent to resist all these conditions seemed to me at first to be almost an impossibility.

In describing the course of the research, I may perhaps be allowed to give a brief sketch of the development of

*A general lecture before the Eighth International Congress of Applied Chemistry.

the subject, and to outline the reasoning which led to the institution of the various experiments. Some idea of the difficulty of the subject will be gathered when I say that Mr. Samuel Bradbury, who so ably assisted me in the work and has kept a record of each experiment, tells me that upwards of 10,000 separate burning tests were made before the solution of the problem was reached. Besides these, a great number of further experiments have since been made to see whether an even cheaper process than that which has now been in commercial use for nearly ten years could be discovered.

I suppose that every one would agree that, at the outset of the experiments, the condition which seemed most difficult of realization was that of finding a substance which not only fireproofs, but which during the process becomes so permanently fixed that it will prove to be absolutely resistant to washing with soap and water or mechanical rubbing. Obviously the substance which is to fulfil these conditions must, in the first place, be insoluble in water and secondly in order that it is not liable to be removed by mechanical rubbing and does not render the cloth dusty, it must be fixed in the fiber and not be merely on the surface. I have already explained that when calico is dipped in a dilute solution of sodium tungstate, and then dried the material possesses in a remarkable degree the property of resisting flame, and then again alum has often been recommended for the same purpose. Now when solutions of sodium tungstate and alum are mixed, an insoluble aluminum tungstate is produced and it is clear that, if this insoluble salt could be fixed in the fiber, the material would certainly be fireproof. It furthermore seemed reasonable to suppose that, as the salt is insoluble in water, it would remain in the fiber even after several washings, and therefore that permanent fireproofing might be achieved in this manner.

A piece of flannelette was therefore soaked in sodium tungstate and, after passing through rollers, to remove the excess of the solution, left for a considerable time in a solution of alum. It was then squeezed, dried and was passed through the same process again with the result that the material became almost as fire-resistant as asbestos. When, however, the piece was thoroughly washed with soap and water, it was most disappointing to find that the greater part of the fireproofing was removed during the first washing, and after several washings the material was little better than the original flannelette.

While this unexpected result was being investigated, it was noticed that aluminum tungstate is soluble in acetic acid and is reprecipitated when the acetic acid is removed by evaporation or by the action of steam and as the precipitate formed seemed granular in appearance, it was thought that this process, if applied to the flannelette, might yield a better result than the process of double decomposition had done. Accordingly, a solution was made up of sodium tungstate, aluminum sulphate and enough acetic acid to dissolve the precipitate, the flannelette was thoroughly soaked in this solution, dried and then placed in an ordinary steamer and subjected to the action of steam until the odor of acetic acid could no longer be detected.

The material was, of course, non-inflammable, and when it was washed it was found that this property was distinctly more resistant to soap and water than was the case in the first experiment, but after several vigorous washings almost every trace of the fireproofing had disappeared. These negative results seemed therefore to indicate that aluminum tungstate was not suitable for the purpose of permanent fireproofing. On the other hand, the failure of this salt was possibly due to some peculiarities in its specific properties and was not considered valid evidence that other insoluble tungstates might not combine more completely with the fiber and thus resist removal by washing.

A careful examination of the tungstates was therefore made and such insoluble salts only selected for experiment which, like aluminum tungstate, are colorless, since it is obvious that a fireproofing agent to be of any use must be capable of application to white cloth without staining it. Several hundred pieces of flannelette were treated under the most varied conditions with all sorts of combinations which it was known would precipitate insoluble tungstates in the fiber, but in no case was a satisfactory result achieved.

However, a fact was noticed which afterwards proved to be of value, and it was this, that, of all the salts, the tungstates of zinc and tin seemed to offer the most resistance to washing with soap and water. Thus, when the material had been thoroughly saturated with a solution made up of sodium tungstate, zinc sulphate and enough acetic acid to prevent the precipitation of the zinc tungstate, and the goods after drying were thoroughly steamed, the fireproofing was certainly fixed to some extent, since it required several washings before the material burnt at all freely. But no amount of variation of the conditions produced a really good result and this combination had therefore to be abandoned. Since the tungstate proved to be unsuitable to the exacting conditions of the problem, a general examination of almost every variety of salt, including ferrocyanides, aluminates, arseniates, antimoniates, zincates and plumbates was made. Many of these could not be employed in connection with wearing apparel in any case because of their poisonous nature, but it was thought that this general examination, which lasted several months, might yield some indication of the type of salt likely to prove resistant to soap and water, if, indeed, such type of salt existed at all. And as a matter of fact these experiments did prove to be most valuable, because when the results were all tabulated, the generalization gradually became apparent that certain soluble salts such as aluminates, antimoniates, zincates and plumbates, in which the oxide of the metal functions as an acid, yielded precipitates, especially with zinc and tin salts which exhibited much greater resistance to washing than the commoner insoluble salts, such as barium sulphate or magnesium phosphate. This generalization ultimately led to a very careful examination of the salts of tin, because, as is well known, the oxides of tin dissolve in alkalis to form stannites, and stannates and tin therefore belongs to the class of salts just mentioned and it very soon became evident that these salts do actually possess the power of combining with the fiber to a greater extent than any of the salts which had previously been experimented with.

In one experiment it was noted that a piece of flannelette, which had first been saturated with a solution of sodium stannate and dried, and afterwards similarly treated with a solution of zinc chloride, was quite non-inflammable. After the sample had been subjected to a vigorous washing with soap and water a considerable amount of the fireproofing still remained, because, when a light was applied to the cloth, it only ignited with difficulty, burned very slowly, and either went out of itself or was easily extinguished on shaking the material.

This development was so promising that the experiment was repeated in a great variety of ways, but, although several results were obtained which were much better than anything which had been seen before, it was disappointing to find that in all cases the greater part of the fireproofing was lost after repeated washings.

In a later series of experiments the first solution was again sodium stannate and the second consisted of sodium tungstate, zinc acetate and sufficient acetic acid to prevent precipitation of the zinc tungstate formed. The result in this case was so good, the material being practically as safe as wool, even after repeated washings, that the first commercial permanently fireproofed flannelette was placed on the market was made on these lines.

It was soon found, however, that the material thus treated had two serious drawbacks: it had a tendency to go damp, and an unpleasant smell of acetic acid remained, even though the material had been steamed and washed, after the fireproofing process, before being sent out. And apart from these two faults, the fireproofing was still not sufficiently permanent and the cost of the process was too great for it to be considered a satisfactory line.

A further series of careful comparative tests seemed to indicate that the undoubted advance which had been made was mainly due to the use of the stannate, and it was therefore decided to carry out a series of experiments using salts of tin exclusively.

The fabric, after being treated with sodium stannate as before, was, in the earlier of these experiments, passed through a fixing bath containing stannous chloride. A very permanent fireproofing was again obtained, but the stannous chloride being a reducing agent, tended to destroy or affect the colors of the material, and the process would, therefore, be generally applicable only to white cloth.

In order to get over this difficulty, stannic chloride was employed, instead of the stannous salt, as the fixing agent, and to avoid any tendering of the material care was taken that the stannic chloride solution should be of such a strength that a little stannate was left unchanged in the material.

An excellent fireproofing was again obtained, for not only did the material show very little tendency to inflame, after it had been washed several times with soap and water, but it had also in such other respects as appearance and feel almost ideal properties, the only objectionable feature being a slight tendency to dust on rubbing and shaking. Now in this particular experiment, in which sodium stannate and stannic chloride had been employed together, the substance which must have been produced in the fiber, and to which the fireproofing must therefore have been due, is stannic oxide, and it seemed clear that this oxide or its hydrate must have some remarkable power of combining with, or attaching itself to, the fiber which enables it to resist removal by washing and rubbing.

But this process still left something to be desired on the score of economy. A certain amount of the tin was undoubtedly wasted, for, in addition to that lost through a portion of the stannate being left unfixed, it was noticed that a considerable amount of the tin oxide which was formed by the action of the alkali of the stannate on the stannic chloride, was not permanently fixed in the fibers of the material, and was therefore removed during the subsequent washing. Tin is so expensive that, in a process to be commercially successful, this loss must obviously be avoided.

There are many ways in which stannic oxide may be precipitated from sodium stannate and one of these, commonly used in ordinary analytical chemistry, consists in adding certain soluble salts, such as sodium sulphate or ammonium nitrate to the solution of the stannate, when the whole of the tin is precipitated as oxide or hydrate. In order to find out whether some process of this kind would precipitate this oxide in such a condition that it would remain permanently fixed in the fiber, a number of pieces of flannelette were soaked in sodium stannate and, after thoroughly drying, separately passed through various solutions containing sodium or ammonium salts at the ordinary temperature and at temperatures up to the boiling point. Although, as was to be expected, the results were not uniformly good, a certain degree of permanent fireproofing was always achieved and consequently the matter was systematically followed up with the result that a process was gradually evolved which yielded material possessing quite remarkable properties. The process is briefly this:

The flannelette (or other material) is run through a solution of sodium stannate of approximately 45 deg. Tw. in such a manner that it becomes thoroughly impregnated. It is then squeezed to remove the excess of the solution, passed over heated copper drums in order to thoroughly dry it, after which it is run through a solution of ammonium sulphate of about 15 deg. Tw. and again squeezed and dried.

Apart from the precipitated stannic oxide, the material now contains sodium sulphate and this is removed by passage through water; the material is then dried and subjected to the ordinary processes of finishing. A long series of trials, carried out under the most stringent conditions, have conclusively proved that material, subjected to this process is permanently fireproofed. No amount of washing with hot soap and water will remove the fireproofing agent, or in other words, the property of resisting flame lasts so long as the material itself lasts. I will demonstrate this by exhibiting four different specimens: (*i*) material as it leaves the process and before washing, (*ii*) material which has been washed 10 times by hand, (*iii*) material washed 20 times in a machine in a laundry, and (*iv*) a portion of a garment which has been in actual use for 2 years, washed every week and is, as you see, in rags. This extraordinary property of resisting soap and water seems to me to indicate that the oxide of tin is not present merely as an insoluble precipitate in the cloth, but must have entered into some actual combination with the fiber, yielding a compound which is not broken down by the action of the weak alkali of the soap. But a matter of hardly less importance from the practical point of view is that the material is not only permanently fireproofed by the process I have just described, it also retains and acquires properties which make it as perfect a material in all other respects as could be desired. In the first place the treatment has no effect on the delicate colors which are now so generally employed in connection with the manufacture of flannelette and other cotton goods, and very careful experiments have demonstrated the fact that the insoluble tin compound in the fiber has not the slightest deleterious action on the most delicate skin. In addition, the presence of the tin compound in the pores gives the cloth a softer and fuller feel than that of the original flannelette, and what perhaps is the most unexpected result is the fact that the material is considerably strengthened by the process.

A series of tests made by the Manchester Chamber of Commerce proved that the tensile strength of flannelette is increased nearly 20 per cent as the result of the introduction of the tin compound into the fiber.

Further and very exhaustive tests made at the Municipal School of Technology, Manchester, on a machine specially designed for testing the wearing properties of fabrics, showed an even greater gain in durability in the case of the fireproofed flannelette. These separate and independent tests conclusively showed that the increase in strength and durability was approximately equal to the cost of the fireproofing treatment, so that garments made from the permanently fireproofed flannelette are, as a matter of fact, no dearer than those made from ordinary flannelette and are at the same time as safe as if made from flannel. Some of these properties and statements may be easily tested by each of you independently with the samples in the little book which you received on entering the hall.

This permanently fireproofed flannelette is now manufactured on the large scale by Messrs. Whipp Bros. and Tod in Manchester under the name of "Non-Flam," and, although its introduction has been slow, it is being increasingly used and will, in all probability, ultimately entirely replace the ordinary inflammable variety. One of the difficulties experienced in connection with its general introduction is the fact, that, owing to the high price of tin, which is now quoted at about £210 or $1,050

per ton, the cost of the process is not inconsiderable but, even with tin at this high price, the extra cost is not more than 1 d. (2 cents) per yard or about 1½ d. or 2 d. (3–4 cents) for a child's garment. I have here on the table, rolls of "Non-Flam" of different qualities so that anyone who wishes for a larger sample than is contained in the little book can easily obtain it.

It is hardly necessary for me to say that this process can be applied to any cotton fabric and is especially valuable in connection with muslin because this material is so often used, especially on the stage, for dresses which, on account of their flimsy nature, are naturally highly inflammable. I have here two strips of the same muslin, one of which has been treated by the "Non-Flam" process without in any way affecting its ordinary properties and was then washed ten times, and the difference in inflammability of the two samples is very striking. While the first sample is highly dangerous, it is difficult to imagine that harm could come to anyone who happened to be dressed in the treated material even if, by accident, a lighted match came in contact with the dress. Another direction in which the process may be used with great advantage is in connection with lace curtains. Many disastrous fires have occurred by reason of the ignition of lace curtains and there can be no doubt that the greater majority of these would have been avoided if the curtains had been treated by the "Non-Flam" process. As an exmaple of this, I have here a strip of lace curtain which has been subjected to the process and than washed a number of times, and it will be seen that if such material did accidentally come in contact with a lighted match, the danger of fire is reduced to a minimum, because even supposing the material did catch fire, the flame is put out immediately by the least shake of the article.

It seems to me that it is obvious that, if this process or some other process capable of giving the same protection from fire, was adopted in the case of all inflammable cotton goods and especially in the case of material used for garments, many disastrous fires and the appalling loss of life especially among young children, might be avoided.

Safety Methods of Storing and Handling Explosive Liquids*

Our Failure to Profit by the Advanced Ideas Developed in Europe

UP to the present time a discouragingly small amount of progress has been made in this country toward ensuring safety in the storage of volatile, highly inflammable liquids, and bringing our methods into accord with the methods that recent experience and experiment have shown to be best. The general subject of storing such liquids has received considerable attention, it is true, from numerous municipalities and corporations, and it has also been considered by various associations and other similar organizations; but there has been no serious and determined effort in any quarter, so far as we are aware, to profit by the advanced ideas that have developed along these lines in Europe, nor even to find out what these advanced ideas are. If this appears to be a harsh and unpatriotic view of the case, we invite the reader to suspend judgment until he has read the present article, and compared the methods outlined herein, with what he may know of the corresponding practice in this country.

We do not wish to belittle the improvements that have been made here, for these have been quite marked, as will be apparent to anyone who will read the present municipal requirements of New York city, for example. The discouraging feature to which we referred at the outset consists in the fact that so little has been done to secure the adoption of the still better methods of storage which have now been worked out, and which have passed the experimental stage so far that they are required by law throughout large parts of Europe, and particularly in Germany, where the closest attention is paid to every matter of this kind.

One type of safety container, in common use in Continental Europe, is the Salzkotten barrel, which was designed by a German engineer named Henze, of Salzkotten in Westphalia. (A simular device is in use to a somewhat limited extent in this country also, but mainly on cans of relatively small size). The Salzkotten device is simply a modified form of the well-known Davy safety lamp, which is extensively used in gaseous coal mines, and in which a fine metal netting serves as a protection against the ignition of the explosive gas mixture. As applied to the gasoline problem, the essential feature is a cylinder of metal netting (or "wire gauze"), with from 144 to 196 meshes per square centimeter, or from 930 to 1,260 per square inch, which is protected inside and outside by sleeves of perforated sheet metal, as will be understood from Fig. 1. The cylinder is closed at the bottom, and its length is varied according to the height of the holder. The opening at the outlet is provided with a screw stopper, in the usual way.

* Copyright 1913 by the Travelers Insurance Company.

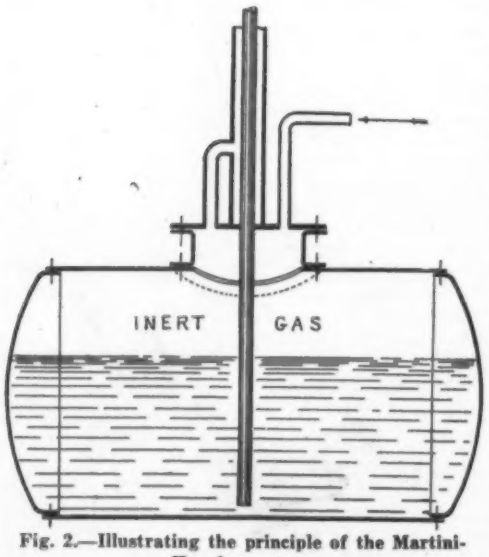


Fig. 2.—Illustrating the principle of the Martini-Huneke system.

The metal netting completely prevents flame from passing through it and igniting the explosive vapors within the vessel that is to be protected. A burning match can be thrown, without danger, into the opening of a holder of this type that contains benzine or gasoline; and it is also possible to pour gasoline from one of these

Fig. 1.—The Salzkotten device.

safety containers into another one, without the slightest danger of explosion, even when the vapor is burning freely at the openings of both. (We do not recommend the performance of either of these experiments, however, because the device is made merely for the protection of the user of the gasoline against accident, and it is not intended for giving spectacular exhibitions.)

To prevent explosion when the holder is heated from the outside by fire or otherwise, the screw stopper is provided with a small safety plug of the alloy known as Lipowitz metal, which melts at 140 deg. Fahr. (or 60 deg. Cent.). When this temperature is reached, the plug melts and is expelled by the internal pressure, and the benzine vapor escapes through the opening and ignites, but without causing an explosion. Vessels of this type and of various dimensions have been subjected to numerous fire tests, and have always been found to be safe from explosion, so long as the wire netting is intact. Since safety barrels and tanks protected in this way have been in use in Europe, the laws regarding the transportation and storage of explosive oils have been changed in many places, the present laws allowing the storage of larger quantities, and imposing fewer restrictions than were previously required.

A safety device, similar to the Salzkotten one just described, has been designed by Lawerentz. This is also constructed on the Davy principle, its essential part consisting of a small, cartridge-like cylinder of metal netting, the mantle of which has a surface only seven times the area of the opening of the holder. The cylinder is attached to the opening of the containing vessel in substantially the same way as in the Salzkotten design, and the screw stopper is also provided with a safety-plug of fusible metal. This device is widely used, and it is prescribed by law in Denmark. It has been thoroughly tested and has never failed to prevent explosions, and it can be specially recommended on account of its simplicity, strength and small cost.

Another device, called the Krater safety cylinder, consists of a corrugated strip of sheet steel, turned in a spiral so as to form a closed cylinder. This is not in such common use, however, and it is doubtful if it is as efficient as either of the two devices previously described.

The Salzkotten and Lawerentz explosion-proof holders are particularly useful for storing benzine or other explosive oils in quantities up to (say) 300 or 400 gallons. For larger amounts another safety method is used, in which the explosive oil is protected by some inert gas, such as nitrogen or carbon dioxide, which prevents ignition and combustion by excluding the oxygen of the air. This system is due to Martini & Huneke, of Berlin, Germany, whose apparatus, first put on the market in 1905, has since come into extensive use. In applying this method, the benzine or gasoline is stored in an iron holder or tank, which is either buried in sand so that its highest part is about three feet below the surface of the ground, or located in a concrete pit at the same depth. During the entire period of storage, and also while filling and emptying the tank, the explosive fluid is constantly covered or surrounded by the inert gas, which is supplied from a cylinder placed near the oil holder, in such a way that the fluid is subject to a constant pressure from three to seven pounds per square inch greater than that of the atmosphere.

The charging and discharging of the storage tank are effected through a conduit or conductor of two concentric lead pipes, the inner of which conveys the inflammable liquid, while the space between the two is filled with the inert gas, and kept always in connection with the gas space in the holder, as shown in Fig. 4. In this way the pipe containing the benzine or other dangerous liquid is always surrounded by the inert protective gas. If a leak should develop in the inner pipe, the gas immediately enters this pipe and presses the fluid back into the holder; and if the outer pipe becomes perforated, the gas will escape into the atmosphere from the annular space between the two pipes, and the pressure will be removed from the system, so that no more fluid will flow up from the tank. The neutralization of the pressure takes place quickly if the breach in the pipe is of any importance, and the level of the fluid in the inner pipe sinks at once.

This system has been thoroughly tried out in Germany, and it has never failed to fulfill its purpose, in preventing ignition or explosion. It is simple to operate, and the isolation is so perfect that no odor from the stored fluid can be detected. In Berlin, there are about two hundred gasoline storage depots built in accordance with this

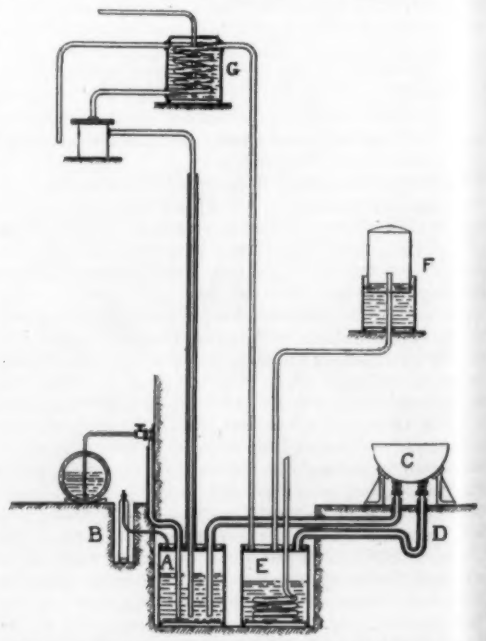


Fig. 3.—Diagram of a benzine-washing plant safeguarded by the Martini-Huneke method.

method, several of them being located in very congested parts of the city. The Allgemeine Berliner Omnibus Aktien-Gesellschaft, for example, stores as much as 32,000 gallons in its depot in Kopenickerstrasse. This particular depot has a special interest, because a five-story building which stood on the same site, and under which a similar quantity of gasoline was stored by the same method, was burned to the ground a few years ago, and the fire destroyed all the piping that was connected with the gasoline tanks, without in any way injuring the tanks themselves or igniting their contents. A severe test like this speaks well for the Martini-Huneke system, and demonstrates its great practical value.

Fig. 3 shows a benzine-washing plant which is in operation in J. H. Dependorff's depot, at Hamburg. It is arranged in accordance with the Martini-Huneke system, has a capacity of about 3,000 gallons per day, and has given no trouble of any kind since it was installed some years ago. In the illustration, *A* is the benzine storage tank, the gas space of which is connected to a carbon dioxide holder, *B*, which serves to force the benzine up into the washer *C*. The impure benzine, after being washed, is discharged through the pipe *D* to a distillation tank *E*, which is heated by a steam coil and connected to a carbon dioxide accumulator *F*. As the distillation proceeds, the benzine vapor rises to the cooler *G*, from which, after being condensed in a coil surrounded by cold water, it gravitates back again into the holder *A*. The benzine in this holder, and in the distillation apparatus, is constantly blanketed and protected by the carbon dioxide gas, which excludes the air and prevents the formation of an explosive vapor mixture. The piping conveying the liquid benzine consists of an inner and an outer tube, as described above, and if a serious leak occurs in either of the two concentric tubes the benzine will immediately flow back into the holder *A* or the distillation tank *E*.

In benzine washeries there is grave danger of self-ignition through the generation of frictional electricity, and the consequent occurrence of electric sparks. This phenomenon has been carefully studied by several authorities, and among others by Professor Richter of Karlsruhe, who has shown that the production of the sparks may be prevented by adding to the benzine a small quantity of oleate of magnesia, in the form technically known as "Richteroel." Prof. Richter and Mr. Otto Behm, also of Karlsruhe, have designed, for use in connection with these washeries, an ingenious alarm apparatus which gives warning when even the smallest electrical disturbance takes place. One of these devices, exhibited at Charlottenburg, was so delicate that it acted without fail whenever a rod of glass or sealing wax, which had been slightly electrified by friction, was brought near the apparatus.

Another storage system for benzine and similar explosive fluids was brought into the market by Grumer & Grimberg, of Bochum, Germany. Carbon dioxide or nitrogen is also used in this case, but only as a pressure medium, glycerine being employed as a sealing fluid between the gas and the inflammable liquid. This system is more complicated than the one described above, and not so safe. The maximum quantity allowed to be stored in Berlin by it, is only 100 gallons. Systems for storing explosive liquids have also been developed recently by Schwelmer, Eisenwerk, Muller & Co., by Julius Pintsch, and by others; but they have not yet been thoroughly tried, and no official reports as to their efficiency are obtainable at present.

LARGE TANK INSTALLATIONS FOR STORAGE.

Several great fires have occurred in petroleum, gasoline and benzine storage-tank plants in recent years, and it is important that the lessons learned from these calamities should be taken into consideration, in connection with present and projected installations. It is believed that the great fire at Blexen, in February, 1909, originated from the ignition of benzine vapors escaping from the tanks through the ventilation pipes—the ignition being effected by a spark from some source, close to the ground. The weather was perfectly calm at the time, and vapors had no doubt collected around the tanks, inside the protecting ramparts. Until recently it has been the custom to carry the ventilating pipes down beside the tanks, to within about ten feet of the ground. The benzine vapor, which is 2.77 times as heavy as air, will naturally collect, especially in calm weather, between the tank and the surrounding ramparts, and an ignition close to the ground is likely to be carried to the tank and to set fire to the liquid. The discharge end of the ventilating pipe should therefore be carried up to a level from 6 to 10 feet higher than the roof of the tank, and should be provided with a hood and with at least three fine-meshed wire nettings of copper, or of other metal that will resist corrosion. Another safe way of taking care of the ventilation vapors is to lead them into a gasometer, and condense them into the liquid form. This makes the plant safer, and the vapors are also saved instead of being wastefully discharged into the atmosphere.

The storage tank should be provided with a very light roof, so that if an explosion should take place the roof will give way without rupturing the walls and allowing the burning liquid to flow out. For the same reason it

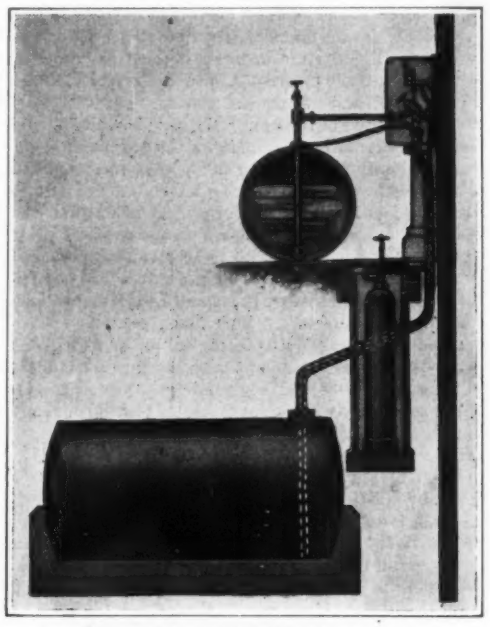


Fig. 4.—The Martini-Huneke system.

is advisable to use light manhole covers on the roof, and to lay them on loosely, in order to give the gases an easy outlet in case of ignition.

In order to cool the tanks during the hot season, a water-sprinkling system should be provided for the roof, or the roof should be built flat and horizontal and be provided with upturned edges so that it may act like a dish and hold a considerable quantity of water.

Electric discharges, due to the generation of frictional electricity, may readily occur in filling or emptying the tanks, and to minimize the danger of ignition from this source the pipes should be made as large as possible, in order to reduce the velocity of the flow, and thereby lessen the friction between the liquid and the pipe walls. The filling and discharging of the tanks should never be forced.

GARAGES.

In garages the safe storage and handling of gasoline is of the greatest importance, because these structures are invariably located in congested places where an explosion would be exceedingly disastrous. If the quantity of fluid to be stored does not exceed 400 gallons or so, the Salzkotten system, described above, is recommended; but for the storage of larger quantities the Martini-Huneke system is more practical and more efficient.

If the garage is detached from other buildings, the roof should be of light metal or concrete construction, and it should contain all the windows that may be required for lighting the interior. In case of explosion or fire, the roof will then give way first, and the walls will probably be left intact. When a garage is located in a building having several stories, it should be well isolated from other parts of the building by fireproof walls, roofs and ceilings. Windows and doors in garages should be of light construction. Their wooden parts should be metal-covered, and all doors should open outward. The floors should be of cement, with good drainage leading to properly located drain pits containing pans for collecting waste gasoline or oil, and these pans should have well-fitting covers of fine-meshed wire netting. The floor should always be kept as free as possible from gasoline drips, and the drain pans should be emptied regularly, and as frequently as may be necessary. The drainage from the floor should never pass directly into the sewer. All oil and gasoline should be removed from it, by a separator or otherwise, before it is permitted to enter the sewer. For cleaning or inspecting vehicles, it is advisable to have special pits built in the floor, about 4 or 5 feet deep and 3 feet or so in width, to give easy access to the under parts of the machines. These pits should be provided with drain sumps for waste gasoline and oil, and the sumps should be fitted with drain pans protected with wire netting as described above. Repairing rooms for vehicles should, if possible, be separated from the gasoline room by fireproof walls. Open lights should never be used in garages. Such artificial illumination as may be required should be obtained by means of keyless incandescent electric lamps, provided with protecting cages or globes. The wiring for the lighting system should be run through entirely closed conduits, with the switches located in a box on the outside of the wall. The room should also be thoroughly ventilated by means of openings in the walls, both at the floor and at the ceiling.

For fire protection, every garage should have a hose constantly connected to a hydrant, and large, well-filled boxes of dry sand or earth should be conveniently placed, for extinguishing ignited gasoline or oil on the floor. For extinguishing small gasoline fires a hand apparatus has been brought into the market containing a chemical mixture which stops the combustion by forming a foam of carbonic acid gas over the burning gasoline.

Volumes could be written on the subject of gasoline storage, and in this article we have treated it only in a superficial and general way. We hope, however, that some of the points that have been discussed will be found useful and suggestive, and that more earnest steps will be taken in this country, in the near future, in the way of placing the transportation, storage and handling of inflammable or explosive liquids upon a safer and more scientific basis. The need for greater education along these lines is pitifully shown, each year, by the heavy toll in human lives, and by the large loss of property, that the methods now widely prevalent involve.

Scientific and Industrial Uses of Diatomite

Most people know that infusorial earth, or *diatomite*, is largely employed in the manufacture of dynamite, but few people realize how extensive are its other industrial uses. France alone imports annually thirty tons of this peculiar sand.

Diatomite is sometimes found in deposits of guano. One variety is known as tripoli and one found in Derbyshire is called English rottenstone.

Under the names of diatomite, tellurine, randanite, ceyssatite, kieselguhr, etc., these earths find many uses, according to their purity and the mechanical means of purification employed at the quarry (combustion to destroy organic matter, washing to eliminate clay and other kinds of sand).

According to *Larousse Mensuel*, a great number of applications rest upon their absorbent properties. Their chemical stability united to their great porosity makes them suitable for solidifying numerous liquids: bromium, sulphuric acid, nitroglycerine. This last becomes, by the addition of diatomite (25 per cent), an easily handled solid, i. e., dynamite. It was the discovery of this faculty of absorption that gave Nobel his prodigious fortune.

This absorbent property is likewise utilized in pharmacy for the preparation of solid disinfectants by the absorption of liquid antiseptics and for preparing dry dressings for wounds; by the manufacturer of cosmetic for hygienic paints and powders; by the packing industry to surround bottles so that any escaping liquid will be absorbed.

The poor heat-conducting qualities of the diatomites make them sought, especially the less pure qualities, for the isolating and incombustible packing used in the construction of furnaces, heating-pipes, powder magazines on ships, the protection of strong boxes, etc.

To facilitate these applications the diatomite is often agglomerated into bricks by the addition of chalk and asbestos. The construction materials thus obtained are very light in weight and suitable for building ice-boxes, cold-storage rooms, etc.

In apartments partitions made of these bricks prevent the transmission of sound.

The fineness of the grains, especially of the tripolis, causes them to be used as abrasives for polishing and burnishing precious metals; the "rays" left by the grains being so fine that a really specular polish is obtained.

Diatoms are also used as inert substances in the composition of coloring matters, gums, matches, etc. The chemical industry transforms them into silicate of soda, cements, sizes for ceramics, ultramarine, and likewise employs them for filters.

Finally, they have sometimes served as foods for a starving populace because of the organic matter contained, but their nutrient value is, of course, somewhat low.

The fine arabesques on their surfaces makes them excellent for the testing of microscopes.

The search for these algæ in guano permits, by the identification of species, the determination of the origin of the fertilizer; in fact, the diatoms swallowed by birds are found in the midst of their *dejecta*.

By the study of these fossil earths geologists, by the determination of species, have been able to solve many problems relative to the *regime* of waters in the early ages of the globe.

The multiplicity of applications shows that infinitely little as the diatom is, it plays an important part on the earth in fixing the silica of the waters and transforming it into a form valuable for its qualities.

The Iron Blast Furnace and the Characteristics of Its Fuels—I*

Definition of Blast Furnace and Classification of Fuels Used

By J. E. Johnson, Jr.

IRON is one of the most common elements in nature. Geologists state that it comprises 7 per cent of the earth's crust and that there is strong proof that the whole interior of the earth below a depth of a few miles is composed of iron. The vast segregations which have gone on throughout geological time have resulted in concentration of iron to all degrees from the lowest up to 72 per cent. The concentration never exceeds this degree for the reason that iron is unlike most other of the useful metals in one important particular. It is seldom or never found native on the earth, except in the form of meteorites which have fallen from space.

This is in consequence of the great affinity of iron for oxygen, with which it will unite under almost all conditions of temperature and chemical environment found on the earth. This brings us to the fundamental fact in the metallurgy of iron which distinguishes it from all the other useful metals.

Its only ores are its oxides. The sulphides which are so important in the occurrence and metallurgy of other metals are not regarded as ores of iron, but only as ores of sulphur.

When the sulphur has been burnt off for conversion to sulphuric acid the iron takes up oxygen to replace the sulphur and becomes an oxide. These artificial oxides then become iron ores under certain conditions and with certain limitations which will be considered later.

But the use of iron sulphide as iron ore either by burning the sulphur off to waste, or directly in the furnace, as is so commonly done with the sulphides of other useful metals, is entirely unknown in the metallurgy of iron.

It is true that carbonates are important sources of iron in Europe, but their carbonic acid is not strongly held and before they are charged into the furnace are driven off by an oxidizing roast which converts the resulting ferrous oxide FeO to ferric oxide Fe_2O_3. This reaction takes place so easily that it will occur slowly under ordinary atmospheric conditions, but with the slight modification in that case that the ferric oxide takes up water of combination and becomes limonite.

More than 90 per cent of the world's production of pig iron is derived from ores which occur in nature as oxides and the remainder comes from the roasted carbonates and the ferric oxide or "pyrite cinder" derived from the sulphides.

From the point of view of the blast-furnace, therefore, it is correct to say that the only ores of iron are the oxides.

The removal of the final traces of oxygen from iron is so difficult that it can commonly only be done with an expensive gas like hydrogen or methane or by solid incandescent carbon, and as the latter is commercially so much more available we may say that industrially iron is reduced only with solid carbonaceous fuel.

Fundamentally then the metallurgy of iron consists of the reduction of the oxides through the use of solid carbonaceous fuel. This operation is carried on to the extent of a few hundred tons per year in the Catalan forge and to the extent of some sixty or seventy million tons in the blast furnace which, therefore, constitutes the foundation of the iron industry.

The blast-furnace is a shaft furnace, the "high-furnace" of France and Germany, and takes its English name from the fact that the air to support combustion must be forced into it under pressure because of the resistance to the passage of the combustion gases offered by its high shaft filled with material. It became, therefore, a "blast" furnace as opposed to a draft furnace, obtaining its air through chimney draft.

The blast-furnace is historically the outgrowth of an attempt to utilize the waste heat of a "low furnace" or Catalan forge so as to reduce the fuel required for the latter and is probably the first industrial application of what is called the counter-current principle.

This may be defined as a method of transmitting the properties of one mass of matter to another by causing the two masses to travel past one another in opposite directions in intimate contact. This process leads naturally also to continuous as opposed to intermittent operation, one of the great desiderata of industrial processes.

This practice has so long and so universally prevailed in the iron industry that it has caused us to overlook one of the most important facts concerning the blast furnace and one to which we shall have occasion to revert many times; namely, that it is an apparatus in which we have merged two distinct processes. First, the reduction of iron oxide to metallic iron. Second, the melting of the reduced material.

The deep fire necessary for melting the "iron sponge" or reduced iron in a reducing atmosphere (without which it would instantly become oxidized again) was not unlike a gas producer in its construction and operation, and consequently discharged a hot gas rich in CO.

The utilization of this heat was the object sought by those early unknown pioneers who added the shaft above the low hearth or Catalan forge, increased the blast pressure to suit, and so transformed it to the blast-furnace.

The fuel economy desired was obtained to such an extent that the low hearth declined to a position of insignificance, although the change brought many other changes not contemplated by the pioneers, some of which were not to their liking.

Most of these must await discussion in a subsequent article, but one was vastly important because it made a radical alteration in the character of the product, and in the process. The original product was tough and pasty, could not be melted but could be "wrought" directly under the hammer, while the product of the improved furnace could not be worked under the hammer, either hot or cold, passing immediately from the brittle solid state to the liquid state in which it could be "cast" or poured. Hence the names of the two principal varieties of iron, "cast" and "wrought."

The production of the iron in the liquid condition contributed further to the continuity of the process since the iron could be allowed to gather in a pool at the bottom of the furnace instead of requiring to be worked out in lumps or "loups" with fire tools, when ready; and the subsequent introduction of a fresh charge of ore.

The shaft-furnace along with these advantages brought a requirement of far-reaching importance. The column of stock must be penetrable by a considerable gas volume at a reasonable pressure. This requirement is just as important to-day as it was in the early day of which I have spoken, though it must be confessed that our ideas of a "reasonable pressure" have undergone great changes.

This penetrability of the stock column may be seriously if not fatally impaired by either of two conditions.

First, the presence of tarry or sticky matter which would fill up the interstices of the charge and make it practically gas-tight.

Second, great fineness of the charge, either of the ore or of the fuel. Moreover, the fuel is subject to a certain solvent action by the gas as will be described later, and this is more active in proportion to the fineness of the fuel so that serious loss occurs if the latter be too fine.

The two principal fuels available, wood and bituminous coal, in their native condition both contain tarry material, but in very varying quantities. The vast majority of their varieties are, therefore, not adapted to use as furnace fuels without preliminary treatment to drive off the tar, so that this condition is industrially of paramount importance.

We can now combine all these necessary conditions to form a fundamental definition as follows:

The blast-furnace is a vertical shaft-furnace blown with air under pressure for reducing iron from the oxides and delivering it in a liquid condition. Its fuel must not be only solid but in lumps of considerable size and must be sufficiently free from tarry components to permit the passage of the gas resulting from the combustion in its hearth.

In addition to these fundamental requirements of a blast-furnace fuel there are others of nearly equal importance.

The three characteristics next in importance to those mentioned are first, purity, particularly freedom from sulphur and phosphorus. Second, porosity or ratio of surface to mass. Third, physical strength or resistance to crushing.

The reason for the importance of *freedom from sulphur and phosphorus* is that next to carbon these two elements exert the most important influence of any of the common constituents in steel, both being destructive of quality if present to an extent greater than one tenth of one per cent. If present in the pig iron of which steel is made they cannot be eliminated at all when certain processes are used and in the others only with increased difficulty and expense. In foundry irons phosphorus is not objectionable within certain limits, but sulphur is as much so as in steel.

The blast-furnace may be so operated as to remove the sulphur in the charge but only with increased cost for fuel and flux and with decreased output and in some cases with reduced quality.

This is not the case with phosphorus, virtually all of which present in the charge goes into the pig iron, in normal operation.

For these reasons sulphur in fuel is always bad and progressively worse as its amount increases, although its removal is possible.

Phosphorus in the fuel, on the other hand, may not be objectionable in any given quantity for certain iron, but if objectionable is prohibitive of the use of that material because its removal in the blast-furnace is impossible.

The importance of *porosity* of the fuel comes from the fact that the velocity of combustion of carbon in air is not infinite but limited. Only a limited amount of carbon per unit of surface exposed can combine with oxygen no matter how favorable the conditions, and in order to secure the rapid combustion necessary to produce high output from a given size of furnace, much surface must be exposed by the fuel.

This cannot be done by reducing its size and so increasing the ratio of surface to volume and mass except to a very limited degree for reasons already explained, and high combustion velocities can, therefore, only be obtained with porous fuels.

The porosity also has a direct bearing on the volume of given weight of fuel, and this also will be shown subsequently to have an important influence on the operation of the blast-furnace.

Physical strength is important because without it no matter how large the lumps of fuel may be initially they are broken by the superincumbent weight of the charge column as the coke descends into the furnace and we have that condition of fineness of fuel which is so objectionable.

On account of the fundamental effects on the operation of the furnace and the quality of the iron caused by these chemical and physical variations in the fuel used, furnaces and the irons they produce are commonly and quite properly classified by the fuels used. These are in the order of their importance as follows: Coke, charcoal, anthracite, raw coal.

COKE.

This subject is so important that large volumes have been written about it, to which those in search of profound information are referred. It is only possible to give a bare outline here.

Coke is a light, very porous fuel produced by the distillation of mineral coal containing sufficient bituminous matter to cement together the whole mass at a certain temperature.

The distillation drives off nearly all the volatile matter and good coke consists almost entirely of fixed carbon and ash.

Coke is made in four ways, of which only two are metallurgically important.

First, in *heaps* or *meillers* on the ground. These heaps are covered with turf and dirt to prevent the access of sufficient air for complete combustion. The limited combustion permitted generates heat enough to drive off the volatile matter from the remainder of the coal, and coke results, but the yield of coke per ton of coal is very small, the cost is high, and the valuable by-products are of course completely wasted in this process.

For these reasons this process is not in industrial use so far as known to me, though it is sometimes used to determine whether a given coal can be coked, and once during the last boom in the iron business it is said to have been used for a short time to secure a supply of coke for a furnace which could not get one otherwise, but the broad statement that the process is not in industrial use stands.

Second, *gas retorts*. One process of supplying illuminating gas for cities consists in distilling a high volatile coal in airtight retorts with external heat. The coke is purely a by-product and is used in part for heating the retorts and in part for domestic and other non-metallurgical uses.

Its quality is very poor, being soft and friable owing in part to the kind of coal from which it is made and in part to the process of manufacture; for this reason it is not used in blast furnaces at all, its interest comes from the fact that the gas retort was one of the progenitors of the by-product oven.

Third, *bee-hive ovens*. These now produce about 75 per cent of all the coke made in this country, and are, therefore, of vast commercial importance.

They consist of a bee-hive shaped structure of firebrick, generally from 9 to 13 feet in diameter approximately hemispherical in shape. They have a floor of firebrick, a doorway about 30 inches wide by 36 inches high, in one side, at the bottom and a charging hole and smoke outlet combined in the center of the dome known as the "eye." These ovens are always built in batteries and

* Reproduced from *Metallurgical and Chemical Engineering*.

frequently in double batteries with the doors in one row on the opposite side to those in the other. The space between them is filled with dirt level with their tops and a track runs over the top of each row to carry a "larry car" which delivers the coal to them. In the case of a double battery, the track may be between the rows, and the larry have a spout on each side to deliver the coal to either row desired.

The track for the larry is in good practice always supported on brick pillars coming up from below the base of the ovens so as to eliminate the jar of the passage of the larry cars from the oven proper, as the life of the latter is seriously curtailed when it gets this continual pounding.

In operation the floor and walls of the oven are heated by maintaining a fire on the floor for several days. Then coal which will fill the oven to about 50 per cent of its capacity is charged through the "eye" in the dome and leveled off. The doorway has previously been built up with brick and clay almost to the spring of its arch which prevents the coal from running out. After the coal is leveled off, the rest of the door is built in the same manner; airtight except that two or three draft holes are left.

In a short time the heat of the oven begins to distill off the volatile matter which ignites and burns in the free space in the dome. This further heats up the coal and causes more volatile matter to distill off and burn in its turn. The whole mass becomes heated and fuses together in a plastic condition, its temperature being a dull red. The gas from the lower portion of the coal forces its way out through the plastic mass with the result that its structure is cellular to a high degree. John Fulton in his work on coke estimates that good cokes have a cell-space of about 45 per cent of their total volume.

As a result of the decreasing combustion when the gas evolution diminishes, the temperature begins to fall and the mass of coke develops vertical cracks.

The process is not finished until the volatile matter is reduced to 1 or 2 per cent. As the amount of volatile matter coming off diminishes by degrees, the supply of air through the draft holes is cut off so that it may be, as nearly as possible, only as much as is needed for the combustion of this gas without leaving any air free to attack the coke itself. The air supply is then shut off altogether and after a few hours a spray-pipe is introduced through the top of the doorway and the surface of the coke thoroughly watered down. As little air as possible is admitted during this operation so as to prevent loss of coke by combustion. After the oven is watered down, the brick door is removed and the coke pulled out with hooks, rakes and other appropriate tools on to the platform in front of the oven where the watering-down process is further carried on if any of the coke is hot enough to require it.

As soon as possible after the oven is empty, the brick door is reset and the oven charged again. This time the heat of the floor and walls of the oven is sufficient to ignite the coal in a short time without any preliminary firing.

The process is then carried on continuously, charging and drawing as rapidly as possible, because after the oven gets too cold it will not ignite the incoming charge of coal at all, or if the charge becomes ignited more of it has to be burned to waste to make up the heat lost by the oven by radiation while standing idle. The work of drawing is laborious and very hot. For this reason oven pullers are among the most difficult of labor forces to keep in regular supply in an industrial organization.

On account of the severity of the labor it is not customary to draw ovens on Sunday, and this, with the necessity for having an oven charged immediately after drawing, necessitates two periods of burning. These are commonly 48 and 72 hours. This is regulated in large part by the size of the charge and in part by the supply of air admitted for combustion. The yield of coke in percentage of the coal charge is larger in good practice with 72-hour coke than with 48-hour, but the yield of coke per oven per day is considerably smaller with 72-hour than with 48-hour coke.

The coke made in the two periods differs to some extent in its physical characteristics. Seventy-two-hour coke is considered harder and, therefore, more desirable for foundry purposes.

The operation of coke ovens on this plan is so simple that it can be done by almost anyone, but in order to get the best results, much skill and careful oversight are required. It is not impossible by superior management to increase the yield of coke per ton of a given coal from 60 per cent to 70 per cent of the coal charged in the same ovens. The matter of drafting is particularly important and a large percentage of the coke in the front of the oven may be burned up by improper draft.

It is considered by some coke-oven authorities very objectionable for all the air to be admitted at the relatively low elevation of the top of the doorway and all in one place because, owing to the delay of the air in becoming thoroughly mixed with the volatile matter as the latter distills, the air has an opportunity to attack the coke.

Owing to these considerations, ovens have been built with an annular passage around the dome above the level of the doorway, this passage communicating with the oven proper by narrow radial slits in the brick work around the circumference of the oven and communicating with the outside air through a draft door. There is little doubt that better results can be secured with this construction if proper attention be paid to it, but the annular passage is likely to become filled with dirt and the narrow ports stopped up. These are difficult to clean out and when this is neglected the oven is no better than the plain oven which costs rather less. With first-class supervision the annular air-passage is probably a valuable feature, but where the operation of the ovens is left to careless and untrained men its benefit would be short-lived.

The volatile matter which distills off from the coal contains a considerable quantity of tar, and during the operation this breaks up at the surface of the mass of coke, presumably owing to the intensity of the radiation in that region, depositing fixed carbon of a beautiful silver-like luster on the face of the coke. If the watering-down is done without admission of much air, this will be cooled below its ignition point before air reaches it and the coke when drawn from the oven will have the silver luster by which its quality has been so widely judged in the past and is even yet to a considerable extent.

Fourth, *by-product ovens.* Even with best practice there is considerable loss of fixed carbon in coking in beehive ovens. Moreover the coal contains valuable by-products, especially tar and ammonia, which cannot be recovered in ordinary practice with the beehive oven. Also, the heat-value of the volatile matter is much in excess of that required for the coking operation. This is plainly indicated by the considerable flame rising from the "eye" of every oven in operation.

In the distillation of coal in gas retorts and its coking in coke ovens we have exactly the same fundamental operation carried on for two different purposes and for two different products. In the case of the retort, the gas is the desired product, the ammonia and tar are recovered from it and sold. The coke is of little value.

In the beehive oven, on the other hand, the gas is distilled off from the coal much as in the retort, but the gas itself is thrown away or burned up, as are its valuable contents of tar and ammonia, the coke itself being the only product.

It was natural that in the course of industrial development attempts should be made to consolidate these two processes and to make simultaneously coke for metallurgical purposes and gas useful for heating and lighting, with the recovery of tar and ammonia. Such attempts began in Europe more than 50 years ago and owing to the greater cost of coal with the lower cost of technical supervision and labor the ovens resulting from these attempts have almost completely supplanted the beehive oven. In America, the opposite conditions prevailing, beehive coke still constitutes three fourths of the total output, but the by-product oven is making rapid strides and it is only a question of time when it will have displaced the beehive oven as completely as it has done in Europe.

In its essentials the modern *by-product* or *retort-oven* consists of a firebrick chamber about 18 inches wide, 6 feet high and 18 feet long, with flues on each side in which gas and air are burned. The ends are closed by metal doors lined with brick set against metal frames built into the brickwork of the oven. Instead of one opening for charging in the top, there are three or more, and instead of the laborious operation of drawing by hand the finished charge is pushed out of the oven by a mechanically actuated ram carrying a sort of rectangular piston of the same general shape as the oven, but somewhat smaller. This is so powerful that it forces the whole mass of coke out at the opposite end of the oven.

There it is caught in a suitable grating or rack, and quenched with a heavy shower of water as quickly as possible. But no matter how quickly this may be done it has had access to the air and enough combustion results to destroy the silver luster characteristic of good beehive coke. This makes the coke look black and lusterless. For this reason furnacemen in the past have frequently been prejudiced against it and in fact it was a matter of years before the builders of by-product ovens were able to produce coke of metallurgical quality equal to the best beehive. But that point has now undoubtedly been reached.

By-product ovens are built in long batteries parallel to one another and only separated by the air and gas flues on each side. The modified "larry" for delivering the coal to them runs overhead as in the beehive oven, but in handling the gas a vast difference exists. No air whatever is admitted to the ovens, the greatest pains being taken to preserve them absolutely air-tight. The gas is taken off through pipes which deliver to a common gas main, and all the gas is sent to a central purification plant where the tar and ammonia are removed and a portion of the gas is then returned to supply the heat needed for the coking process. The rest of the gas is available for either city lighting or industrial purposes.

In order to maintain the high temperature necessary to force the heat for coking through the firebrick walls of the ovens, regenerators are commonly used to preheat the air for combustion, and where regenerators are not used recuperators are substituted for them. The results obtained with these latter are not so economical of gas as those obtainable with the regenerators and the best practice tends more and more strongly to the use of the regenerator oven.

These regenerators are commonly built as the substructure of the oven itself. Sometimes each oven has its own separate regenerator, and in other cases the regenerators are common to a whole battery of ovens.

The first two types of ovens to achieve commercial success in America were the Semet-Solvay and the Otto-Hoffman. The former design uses horizontal flues, the latter vertical. In more recent years the Koppers oven or ovens, of which it is the prototype, have taken the lead over the other two. These have vertical flues like the Otto-Hoffman oven of an earlier date, which they have largely replaced.

The yield of coke with the by-product oven is always higher than with the beehive. In fact, the quantity of fixed carbon in the coke is greater in good practice than the fixed carbon in the original coal.

This apparent paradox comes from the fact that during the operation the tar and volatile matter of the coal are broken up by heat as described for the beehive oven, but unlike the latter the by-product oven does not permit the combustion of any appreciable fraction of the coke produced. The consequence is that the fixed carbon of the coal is augmented by the fixed carbon resulting from the breaking up of the bituminous matter without any loss through combustion.

A wider range of coals can be successfully coked in the by-product oven than in the beehive, though, on the other hand, some coals that can be successfully coked in the beehive oven swell to such a vast extent during the distillation of their volatile matter that it is impossible to push them from the by-product oven. These, however, are few in number.

Much attention has been paid to the best percentage of volatile matter for coking purposes in by-product ovens and its line of commercial development has been very different from that of the beehive oven. The latter has very generally been built as close to the mouth of the coal mine as possible with the object of avoiding transportation charges to the point of consumption of the volatile portions of the coal, and as the yield from such ovens is relatively small, this is an important consideration.

With the by-product oven, on the other hand, the yield of coke is very much larger and moreover the gas is of great value, as above mentioned. In addition to this, the by-product oven will do its best work on coal of a certain content of volatile matter approximately 25 per cent. This is naturally not always found in nature.

The volatile matter in coking coal covers a wide range. It is only from 18 to 20 per cent in the excellent coals of the New River and Pocahontas field and as high as 40 per cent in some other coals. The coal of the Connellsville district contains from 27 to 30 per cent.

In order to secure the advantage of coal the nearest possible to the exact composition desired, recourse is often had to mixtures of different varieties of coals. Mixtures of two are common and mixtures of three or more are sometimes used. Such mixtures enable the best results to be obtained in yield and quality of coke, in quantity of gas and reduction of coking time.

The advantage of making mixtures operates in the same direction as the value of the gas and the yield of coke in making it very desirable to place the ovens at the point of consumption of the coke rather than at the mouth of the mine. These considerations are so powerful that by-product ovens are almost always so located.

(To be continued.)

The New and the Old in Science.—That the marvel of to-day is the commonplace of to-morrow is a familiar observation, and the history of science and invention furnishes innumerable examples of this fact. A French journal cites the case of the recent disaster of the steamship "Volturno." While so much has been made of the part played by radiotelegraphy in saving the lives of the passengers and crew, no one has mentioned the fact that practical astronomy was an equally essential factor in their rescue. Of what use would have been the SOS message, if mariners had no means of accurately determining their position at sea? One might carry this idea further, and ask how, even with wireless communication and accurately known positions, the rescuers could have arrived in time to be of service, but for the speed and independence of wind and weather ensured by steam-propulsion.

On the Imprisonment of Radiation by Total Reflection*

By Prof. R. W. Wood, LL.D.

My attention has been drawn by Dr. Cooper Hewitt to a somewhat surprising circumstance in connection with fluorescence. As is well known he has now perfected his rhodamine fluorescent reflectors for the mercury arc to such a point that the red fluorescent radiation, plus the direct light of the arc, makes a fairly good imitation of daylight. He found that if the celluloid film stained with rhodamine was backed by white paper the fluorescence was many times brighter than when a backing of silver paper was used. I verified the matter by depositing silver chemically over a small circular area in the center of a white porcelain plate, and flowing the whole with the rhodamine solution, or with water containing a little fluorescein. Notwithstanding the very high reflecting power of the polished silver film, the intensity of the fluorescence over the circular area was so feeble that it appeared almost black in contrast with the brilliant fluorescence displayed over the surface of the porcelain. The plate was illuminated with the mercury arc in the case of the rhodamine, or with that of the carbon arc passed through dense cobalt glass in the case of the fluorescein, the experiment being well suited for lecture purposes. If we strip off the colored celluloid film from the porcelain plate we find its fluorescence becomes even less brilliant than that of the portion backed by silver. The action of the white porcelain surface in raising the intensity of the fluorescence of the film covering it appeared a little puzzling at first. It was noticed, however, that the films which had been stripped from the surface glowed brilliantly *along the edges*, and this circumstance gave me the clue to the action of the matt reflecting surface. The greater luminosity of the edges was evidently due to the circumstance that more radiation was able to escape here than through an equal area of the surface of the film. The action of the matt surface will be clear on reference to diagram in which AB respresents the upper, and CD the lower surface of a celluloid film stained with rhodamine. Let X represent a fluorescent molecule from which radiation of equal intensity escapes in all directions. Of all the rays leaving X it is clear that only those within the solid cones EXF and GXH can escape into the air. The rays within the cones FXH and EXG are imprisoned by total internal reflection, the ray XJ for example being reflected back and forth between the parallel surfaces of the film. Silvering the lower surface will cause the rays in the cone GXH to escape through the upper surface, but will not affect the paths of the other rays. If now we bring a white matt surface into optical contact with the lower surface of the film, it will liberate all of the rays which were totally reflected. Take the rays XJ for example; it is diffusely reflected at K, and that portion of the energy within a cone of the same aperture as that of the cone EXF escapes through the upper surface. The rest is totally reflected from the upper surface, and returned to the white surface, when the process is repeated, all of the energy, except that lost by absorption, eventually passing out through the upper surface. The action of the matt surface liberates the energy imprisoned by internal reflection. If there were no absorption the edges would appear of dazzling brilliancy, as all of the imprisoned energy would be thrown out here. The greater brilliancy of the edges of a fluorescent film was utilized by Becquerel in observing the faint luminosity of certain compounds of uranium, and by Greinacher in the case of the fluorescence of mica films caused by radio-tellurium (*Phys. Zeit.*, 1906).

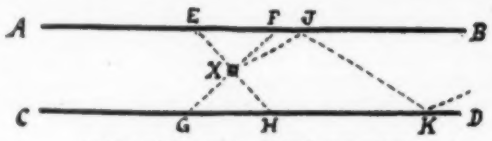
We may test the above theory of the action of a matt surface in increasing the brilliancy of the fluorescence by making photometric measurements. The ratio of the energy within the two cones of rays which can escape without the aid of the matt surface, to the energy imprisoned by reflection, is represented by

$$\frac{1 - \cos\theta}{\cos\theta}$$

which is the ratio of the area on a sphere described around the luminous molecule, cut out by the cone of rays EXF to the area of the hemisphere minus this portion. For celluloid the critical angle is about 40 deg., i. e., $\theta = 40$ deg. and

$$\frac{1 - \cos\theta}{\cos\theta} = 0.31;$$

In other words, the imprisoned energy is about 3 times greater than the energy which escapes. Its liberation by the matt surface should therefore give us about four-fold increase in luminosity. This point was tested with the photometer. As a standard source a rhodamine screen (matt) illuminated by the light of the mercury arc was used, its light being passed through two nicol prisms by which its intensity could be varied by a known amount. It was compared with a rhodamine film in part covering white porcelain, and in part highly polished silver. The photometer used was a very simple but very satisfactory one made by Dr. Pfund, a semicircle of silvered glass taking the place of a Lummer-Brodhun prism. Equality of luminosity of the two fields of the instrument, with disappearance of the dividing line, was secured in the two cases with the nicols rotated 11 deg. and 22 deg. from the position of extinction. This means that the rhodamine film on porcelain is 3.8 times brighter than the one on silver, which is in good agreement with the calculated value (4). In making the observations a red glass was placed in front of the photometer to exclude everything except the fluorescent light. (White porcelain alone, illuminated by the mercury arc, appeared practically black when viewed through the red glass.) On completing the work it occurred to me that



Action of the matt reflecting surface.

the case was similar to the one to which I drew attention several years ago, namely, that a fused bead of microcosmic salt, raised to the highest temperature possible with a blast lamp, emits little or no light when removed from the flame, though the platinum wire supporting it glows vividly. This is of course a fine case of the failure of a transparent body to radiate, which is what Kirchhoff's law demands. But as the bead cools down it solidifies and numerous cleavage planes appear. At the moment of crystallization it glows with a dull red light, which persists for several seconds. I found difficulty in explaining this (see Phys. Optics, 2d edition, page 598) but a suggestion made by Prof. C. E. Mendenhall certainly gives us a satisfactory hypothesis, though there still remain some points which are not quite clear to me. Prof. Mendenhall considered that the action of the cleavage planes was merely that they interfered with the imprisonment of radiation by total reflection. All rays originating within the ball which strike the surface at an angle greater than the critical angle are reflected around the inner surface over and over again, so that they eventually may be considered as having traversed a layer of the medium of infinite thickness. If the medium has any absorption at all, and no media are perfectly transparent, this radiation will be of the same type as that of a black body at the same temperature. Scratches on the surface or internal cleavage planes liberate this energy by interfering with the total reflection.

Prof. Mendenhall has suggested that I include some of his observations in the present paper.

He writes me that he made a scratch on the surface of a ball of fused quartz, which was then heated in a Bunsen burner. The black body temperature of the scratch, as observed with an optical pyrometer, was 850 deg. Cent., while that of the rest of the ball was barely 600 deg. Cent.

From similar considerations he concludes that a uniformly heated, nearly transparent sphere should appear more luminous toward the limb. (A solid incandescent sphere appears as a uniformly illuminated disk, as a result of the cosine law.) I have verified this with a hollow glass bulb filled with a very dilute solution of rhodamine, illuminated by the mercury arc and viewed through red glass. If a spot on the surface of the bulb is finely ground with flour emery, this spot appears extremely luminous when near the limb, as a result of the liberation of the fluorescent rays which are undergoing total internal reflection. The bulb appears slightly more luminous at the limb, even when the surface is not roughened. I have observed the same thing in films of celluloid stained with rhodamine, which appear much more luminous when viewed obliquely, at nearly the angle of grazing emergence, than when observed by rays which leave the surface nearly parallel to the normal.

In the case of the fused bead of microcosmic salt it is possible that the increase in brilliancy which accompanies the formation of cleavage planes is due in part, if not wholly, to the reflection and refraction of the light emitted by the white hot supporting wire. I have not been able to devise any satisfactory way of getting rid of a luminous support, but I have dropped molten beads from the fifth floor of the laboratory and watched their descent down the five stories of the dark hallway at night. The glow appeared to decrease steadily with the descent, which indicated that there was no increase of luminosity. If the bead could be held stationary in a strong vertical current of air, the condition for observation would be more favorable.

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The World's Coal Supply

The International Geographical Congress has issued a monograph on the coal resources of the world. Sixty-four countries are dealt with, the information having been supplied by government departments and specialists who had studied particular fields. One of the most interesting sections of the report deals with the world's coal reserves, the total of which is given as 7,397,533,000,000 tons. Of the anthracite fields, Asia, with the great Chinese fields, has by far the greatest supply of any of the great continental divisions, furnishing 407,637,000,000 tons.

The world's production of coal for 1910 was about 1,145,000,000 tons, so that, allowing for areas which cannot be economically mined, there is still enough left for many hundreds of years. In individual countries, however, the end is in sight already.

Great Britain is estimated to have a reserve of 189,534,000,000 tons, most of it bituminous, while France has 17,584,000,000 tons, also chiefly bituminous. Switzerland has almost depleted its coal supply, while Turkey has large quantities of brown coal and cannel-like bituminous. Germany's actual reserve is 94,865,000,000 tons of brown coal, though it is said to be probable that there is a large further reserve. The reserve of Russia is given as 235,997,000,000 tons of all grades.

While there are five hemlocks in the United States, only two are of any commercial importance, common hemlock and western hemlock. Of these two, western hemlock makes the better lumber.

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Table of Contents

PAGE
Progress in Locomotive Design.—6 illustrations 97
Catastrophic Instability in Aeroplanes.—By F. W. Lanchester.—8 illustrations 98
Speed for Turning Unusual Materials 99
The Moving Picture in the Machine Tool Business.—By Chester L. Lucas.—6 illustrations 103
Coloring the Wood of Growing Trees 105
The Permanent Fireproofing of Cotton Goods.—By Prof. William H. Perkin 106
Safety Methods of Storing and Handling Explosive Liquids.—4 illustrations 108
Scientific and Industrial Uses of Diatomite 109
The Iron Blast Furnace and the Characteristics of Its Fuel.—I.—By J. E. Johnson, Jr. 110
On the Improvement of Radiation by Total Reflection.—By Prof. R. W. Wood.—1 illustration 112
The World's Coal Supply 112